Ensuring future resilience to pests and diseases
- a multi-disciplinary approach

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The James Hutton Institute

University of Exeter

What will the Scottish arable and horticultural sector look like in 10 years' time and how resilient will it be to pests and diseases?

Workshops with agriculture stakeholders to characterise future drivers of change based on analysis of past events

Five STEEP factors used as a framework:

Social
- Costs of living.
- Dietary health and education.
- Labour changes.
- Social media.
- Food production.
- Training and farmers networks
- Demographics in farming population.

Technological
- Next generation genomics
- G.E and advanced plant breeding
- Research and Development
- Precision AG
- Robotics
- IPM
- Novel crops/novel pests
- AI, big data, forecasting.

Economic
- EU market.
- Investment in infrastructure.
- Supermarkets dynamics.
- Changes in food prices.
- International trade.
- Farmers profitability.
- Agricultural support.

Environmental
- Extreme weather events.
- Pollution levels.
- Net zero targets 2045
- State of nature and biodiversity loss.
- Novel pests and disease.
- Changes in land use.
- Rewilding and forestry.

Political
- Net zero, Biodiversity, Food security
- Climate target
- Devolution (legislation Independence)
- Agricultural policy.
- International trade, Brexit.
- Geopolitics
- Societal pressures (NGOs etc).

Which of the STEEP drivers of change are most uncertain?

= 'Critical Uncertainties'

Stakeholders asked to assess '*what if?*' these 'critical uncertainties' happened, and what are the better and worse case scenarios

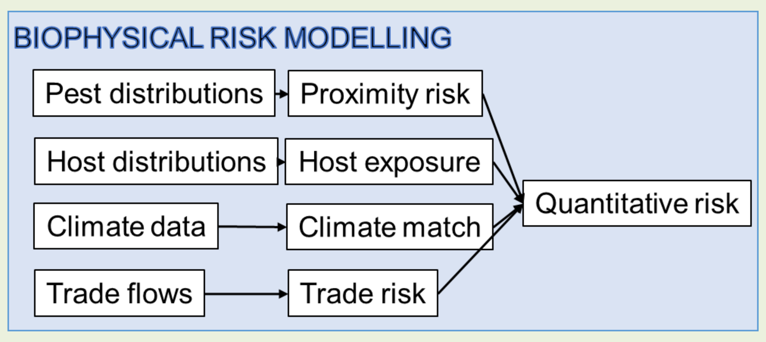
Used to build these morphological boxes*

*Don't worry about the detail

Critical uncertainty	Plausible Level 1	Plausible Level 2	Plausible Level 3
Food production. Disconnection between people and land farming.	Strong connection between people and food production (i.e. through local markets). Willingness to pay for higher quality food. Willingness to pay for surveillance. More diverse crops. More resilience		Total disconnection between food production. If people c where their food comes from eat, then there is no interest in and diseases. Perception of difficult to accept changes in f Low influence on food p
Diets and consumer education	High awareness of food production and more demand for healthy food and better quality is demanded.	Consumers education on diets and food production is fragmented and lack of understanding	Consumers are not interest production. Complete lack of
Precision Agriculture. AI Tools	Increase in the use of precision targeted farming. Controlled use of pesticides prevents resistance developing in pests	No change from current circumstances If continued use of pesticides = resistance development.	
Gene editing	GE is banned and does not represent an option in Scotland.	GE continues to be in state of uncertainty.	GE is accepted in Scot
Changes in Food prices & Food Affordability	Costs of living and production are very cheap. More home grown food and more control with less pests. Higher standards.	Costs of living/production food is affordable. Consumers have a choice to think of quality = less pests, land management to help reduce pressure. Differences between cereals and fruit = reduced inputs may not cause a diminution of crops.	High cost of living/productio expensive. Reliance on imp more exposure to plant pe diseases. Costs of production are hig shrinks and more need to re imports
Farmers profitability. Economic instability.	Farmers are economically fragile, but slow reversal of profitability declines from 2020s starts to improve farmers' economic resilience.	Farmers are economically fragile and decline from 2020s continues at the same rate	Farmers are economically f decline from 2020s accelerate very vulnerable farming s
Extreme weather events & Climate warming, weather unpredictability	Weather becomes warmer and drier. Longer period of exposure/ crop damage. Less pressure from slugs, rust, fungus – with warmer, drier weather. Ability to grow a wider variety of crops = more resilience. Invasive species from continent. Opportunity to learn from other countries.	More extreme events, flooding, drought. Longer periods of exposure/crop damage More difficult to manage unpredictability Difficult to predict crop drought and floodings. Sudden plant pest and pathogen infestations.	Weather becomes warmer a Range of new pests and pa i) wet weather it harder to c Longer periods of attack/ cro
Weather annual variation	Better systems in place to predict weather extreme events, creating a more resilient system.	Extreme weather events higher frequency but more predictability.	Weather event unpredicta extremely high.
International trade. Geopolitics (Brexit, EU/UK policy divergence, other parts of the world)	Protection regime/restriction increased. Fewer pests and better information if system is effective. Less use of chemicals Different impact on food quality, higher prices More diversification	UK has some limited restriction/protection, Scotland could voluntarily introduce restrictions. Divergence between Scotland and the rest of the UK (with threats and opportunities). Fewer pests.	UK has no restrictions / protec Risk of entry of non-native/ More pressure to remove con minimise production c Pressure to aim for commodity market. More pests= increase pesti
Net zero targets 2045	Targets set for reduction of pesticides, GHGs, fertilisers and other targets are achieved at 50%		Targets set in reduction of p GHGs, fertilisers and other t missed, and none are ac

'How severely would your scenario be impacted?'
by pests and pathogens predicted to pose a risk to Scottish agriculture

Stakeholders were asked to imagine that three pests and diseases, predicted as threats from biophysical modelling, are well established in Scotland in 2033



Morphological boxes used by stakeholders to develop 'better not best' and 'worse not worst' case scenarios

'Scotland's own vision'

'Agriculture elsewhere'

'Scotland feeds the world'

"Crisis is Scotland's opportunity"

Stakeholders' recommendations to mitigate against future pest and disease threats

- Invest in R&D and in the people involved in farming
- Review future chemical and biological control products
- Help growers invest in monitoring and prevention
- Educate consumers on the impact of their food choices
- Access to credit or assurance schemes to buffer losses and maintain viability

Read the full report:

Participatory research with stakeholders to test integrated pest management methods

Collaborative trials with farmers and agronomists to test **new cropping practices, crop varieties, pesticide alternatives, biological controls** and **pest monitoring tools** to control emerging pests in soft fruit and potato crops

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RESAS Rural & Environmental Science and Analytical Services

Plant Health Centre Scotland's Centre of Expertise

This work was supported by the Underpinning National Capacity (Pest collections project) and Strategic Research Programme (Project JHI-A1-2: Integrated Crop Protection) funded by RESAS. Special thanks to the stakeholders who participated in the scenario planning activities and the farmers and growers collaborating with us in IPM research trials.

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Ensuring the right information gets to the right people in the right way and at the right time

CREW CENTRE OF EXPERTISE FOR WATERS

By Amy Cooper, Rebekah Burman, Maureen Whalen, Nikki Dodd and Rachel Helliwell

Navigating Water Scarcity: Impacts, Adaptations, and Future Predictions for Scotland's Land Use and Industries

Background

Scotland is experiencing **climate change** at an unprecedented rate, leading to emerging risks such as **water scarcity.** This shift in climate is expected to bring further changes in seasonal precipitation patterns, increasing the **frequency** and **severity** of droughts. **Adaptation** is vital.

Scotland's Response to Water Scarcity Amid Climate Crisis

University of Dundee · sepa · Scottish Water · NatureScot NàdarAlba · WICS · Consumer Scotland · Scottish Government Riaghaltas na h-Alba gov.scot

Project outputs →

Approach

- Collate evidence to inform and prioritise mitigation options and adaptation actions to address future water scarcity challenges in Scotland.
- Expert workshop held, and a logic model, story map, report and summary produced.

Key Findings

- Recommended a short- and long-term programme of actions, including establishing a governance structure with representatives from relevant agencies, businesses, and communities.
- Focus on enhancing national water resource planning and promoting improved water stewardship across society.
- Need for immediate, decisive action to safeguard Scotland's water sector and ensure it remains a leader in sustainable water management.

Impacts & Outcomes

- Evidence presented in SSAC Scottish National Adaption Plan (SNAP) and Scottish Government Water Scarcity round tables
- Broadcast on STV's News at Six, That's TV, Radio Tay, Kingdom FM and Original 106
- CREW Spotlight
- News articles across 7 newspapers including...

The Courier · Scottish Daily Mail · The Herald · The P&J · Scotland on Sunday

Scotland's Future Water Scarcity: Impact on Distilleries & Agriculture

The James Hutton Institute · University of Aberdeen · BGS · SRUC · sepa · NatureScot NàdarAlba · NFU Scotland · Scottish Canals · WICS · Scottish Government Riaghaltas na h-Alba gov.scot

Project outputs →

Approach

- To predict water scarcity in Scotland and impacts for crop producers, livestock producers and distilleries.
- Focus groups, and tailored infographics, policy brief, report and summaries

Key Findings

- Eastern Scotland is expected to experience a summer climate-water deficit, with surface water droughts likely to double by mid-century.
- Groundwater resilience is also a concern, especially in low-storage areas.
- There is a need for more data on water use by abstractors, expanded monitoring and analysis of groundwater resources, and strategies to overcome barriers to adopting available adaptation responses.

Impacts & Outcomes

- Farm Advisory Service podcast and YouTube videos

Farming & Water Scotland

- Farming and Water Scotland newsletter
- CREW & University of Aberdeen spotlights
- Featured in articles across 12 media sites including:

The Scottish Farmer · smart water magazine · The Geographer · The Scotsman · irelandlive · The National

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Using vertical farming systems for adapting nutritional content of crops

1495 UNIVERSITY OF ABERDEEN
The Rowett Institute

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Have a look inside a vertical farm and learn more about our research

Introduction

- With population growth and rising shortages of farmland for local urban food supplies**, vertical farming has the potential to support local food production and security** (1)
- The growing system footprint is reduced by growing in three dimensions and as a result allowing **the opportunity of urban food production using derelict and/or poorly used land** (2)
- Vertical farming as a Total Controlled Environment Agriculture (TCEA) system provides **new opportunities for tailoring crops to achieve sufficient nutrient supply on a population level**

The aim of this study was to **investigate the nutritional quality of produce grown in a vertical farming system and..**

1 …the suitability of different crop types for biofortification with zinc and iron

WHY?

Micronutrient intakes, including iron and zinc, are **below the recommended daily intake** in the UK (3)

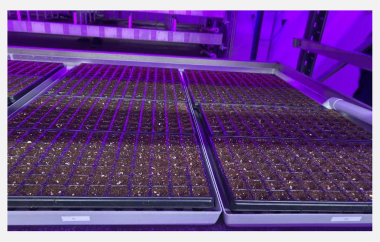
Both iron and zinc play **critical roles in human nutrition** (4)

HOW?

Kale Babyleaf (*Brassica oleracea*)

Kale Microgreens (*Brassica oleracea*)

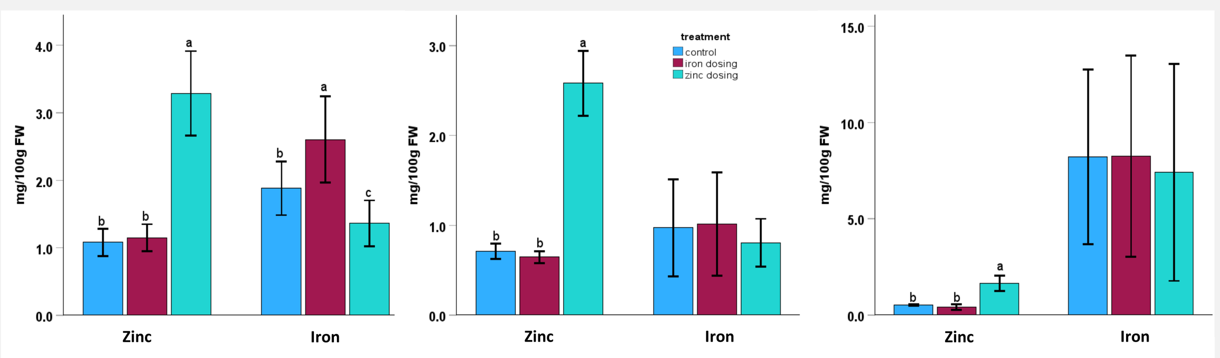
Pea microgreens (*Pisum sativum*)



3 conditions:
(1) **control** (standard nutrient solution)
(2) **Zn dosing** (+20 mg L^{-1} zinc in the nutrient solution)
(3) **Fe dosing**(+20 mg L^{-1} iron in the nutrient solution)

Mineral concentrations

Zinc and iron levels in 100g fresh plant material under 3 treatments



➢205% increase in zinc levels
➢38% increase in iron levels

➢264% increase in zinc levels

➢217% increase in zinc levels

Zinc or iron reference nutrient intake covered by 30g of fresh plant material from zinc or iron.

Crop	Fe-treated		Zn-treated	
	% RNI of Fe		% RNI of Zn	
	Men	Women	Men	Women
Pea microgreens	9	5	10	14
Kale microgreens	28	17	5	7
Kale babyleaf	4	2	8	11

2… the effects of different red-to-blue ratios (R:B) of the LED light spectrum

WHY?

Controlled lighting systems can be utilized to **influence plant growth rates, yield and composition** including **important nutrients and health-beneficial phytochemicals** (5)

The consumption of **plant foods high in antioxidants** (rather than isolated supplements) **is associated with a lower risk of chronic oxidative stress and the related symptoms** (6)

HOW?

Micro Amaranth Red Aztec (*Amaranthus tricolor* L.)

Red Batavia Lettuce (*Lactuca sativa* L.)

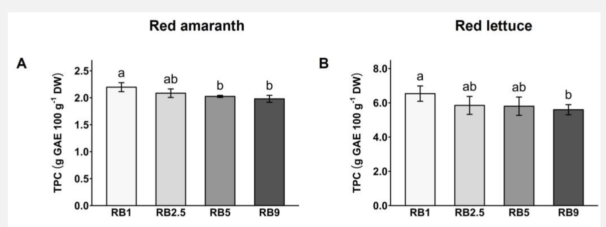
Grown under 4 different light recipes:

Treatment	R:B ratio	Spectrum (Percentage intensity) Blue (%)	Green (%)	Red (%)	Far red (%)	PPFD (µmol m^{-2} s^{-1})
RB1	1	44	5	44	7	253
RB2.5	2.55	25	5	64	7	255
RB5	5	15	5	74	7	255
RB9	9	9	5	80	7	254

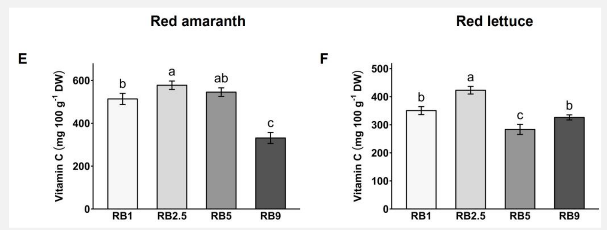
Biometrics and antioxidant components & antioxidant capacity

A higher proportion of red light **affected growth** with increased stem height

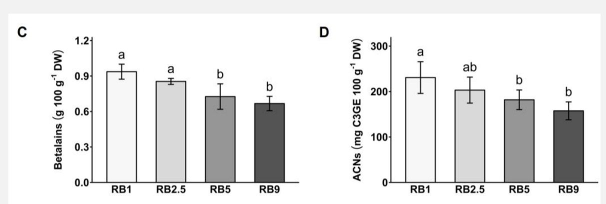
The increase of the blue light fraction resulted in the **upregulation of antioxidative components and antioxidant capacity**



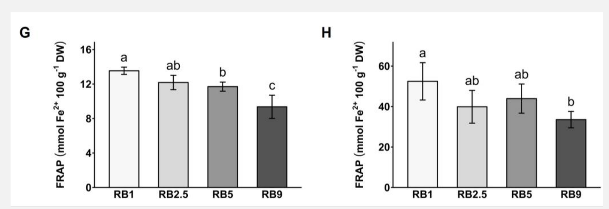
Polyphenols



Vitamin C



Betalains and anthocyanins



Antioxidant capacity

Conclusions

- The crops investigated in the study were **suitable for biofortification with zinc, while only the pea microgreens were suitable for both zinc and iron biofortification.**
- **The zinc dosed crops could cover up to 14% of the recommended nutrient intake (RNI) for zinc.**
- **The iron dosed crops could even cover up to 28% of the iron RNI**
- It is possible to **increase zinc concentrations while simultaneously increasing health benefitting components** e.g. glucosinolates in Brassicaceae species.
- Light ratios had a **significant influence on the growth** of red amaranth and red lettuce as well as on the **accumulation of plant secondary metabolites**
- Our findings demonstrate that it is possible to use LED lights in a vertical farm setting to **modulate, possibly enhance, the phenotypic properties and/or nutritional quality of crops**, using different ratios of red and blue light.
- Overall, **light recipes can be individually tailored** according to the type of crop as well as the desired outcomes

To determine the effects on human health of plants grown in vertical farms, human studies need to be conducted in which the effects of differently grown produce can be observed and analysed.

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Acknowledgements
We thank Sarah Auld for her technical support

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Surveillance for Antimicrobial Resistance in Livestock Units and the Surrounding Environment

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RESAS Rural & Environmental Science and Analytical Services

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SRUC

What is antimicrobial resistance (AMR)?

AMR occurs when bacteria, fungi, viruses and parasites adapt and stop responding to antimicrobials.

Why do we care?

Globally recognised as one of the major One Health issues affecting the world today (WHO, 2014).

AMR threatens our access to effective antimicrobials.

Human deaths from antibiotic resistant infections projected to increase 43% from 2014 – 2050 (He et al.,2020).

What is the problem?

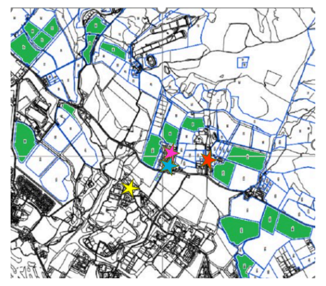
The UK currently **does not have** a national surveillance strategy for the environment.

Key knowledge gap in the role **livestock play** in the transmission of AMR to humans and the shared environment.

This study i**nvestigates the AMR pollution risk** from **livestock units** to the **surrounding environment.**

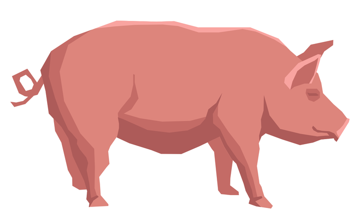
What did we do?

Carried out surveillance for AMR in the environment linked to livestock usage.



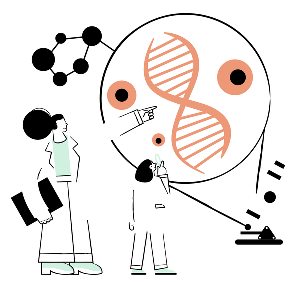
A study site was chosen with four closely co-located livestock units (pigs, cattle,sheep and chickens).

Fields were selected based on manure application and grazing history, giving four field categories



Livestock Units (pigs and cattle), samples of faeces (pen floor), slurry and manure, mice (faeces from colon).

Environment, samples of soil and vegetation, mice (faeces from colon)



Shotgun metagenomics were performed to investigate the AMR gene profile in all of the samples

Results

AMR gene count in **pigs** is considerably **higher** than in **cattle, soil and mice** (Fig1) .

Of the **475 genes** identified, **30% were found to be shared** between the **mice and pigs** (Fig 2).

With **8% of the genes being found in all four sample types** (Fig 2)

Outcome

This work will **enhance** our **understanding** of AMR acros**s livestock systems and their linked environments**, supporting **Scotland's contribution to the UK's national action plan on AMR.**

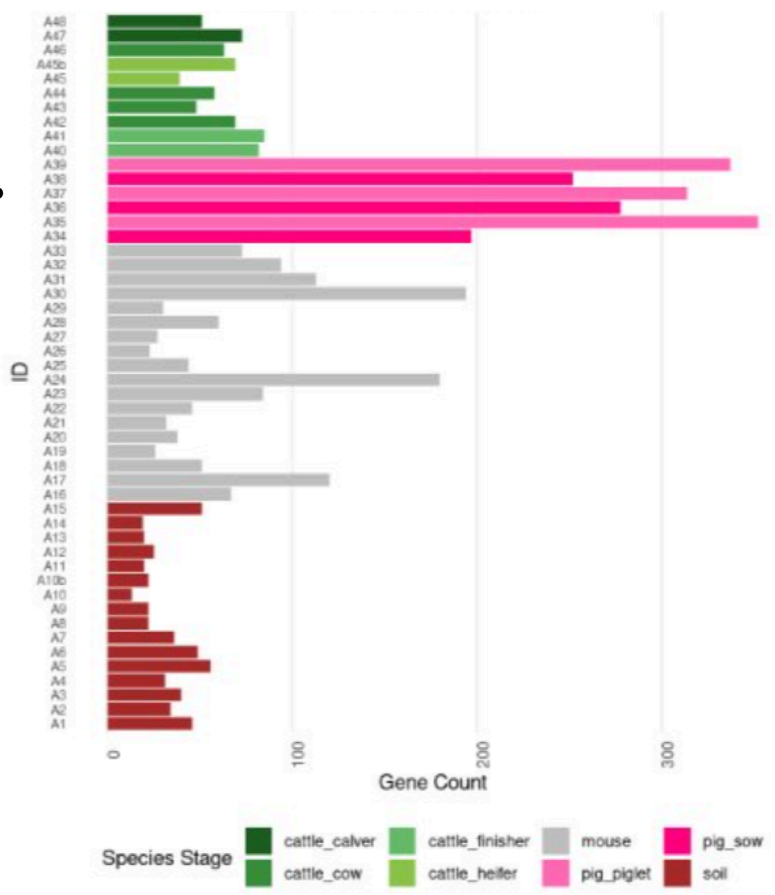


Figure 1 AMR gene count by sample type (n=48)

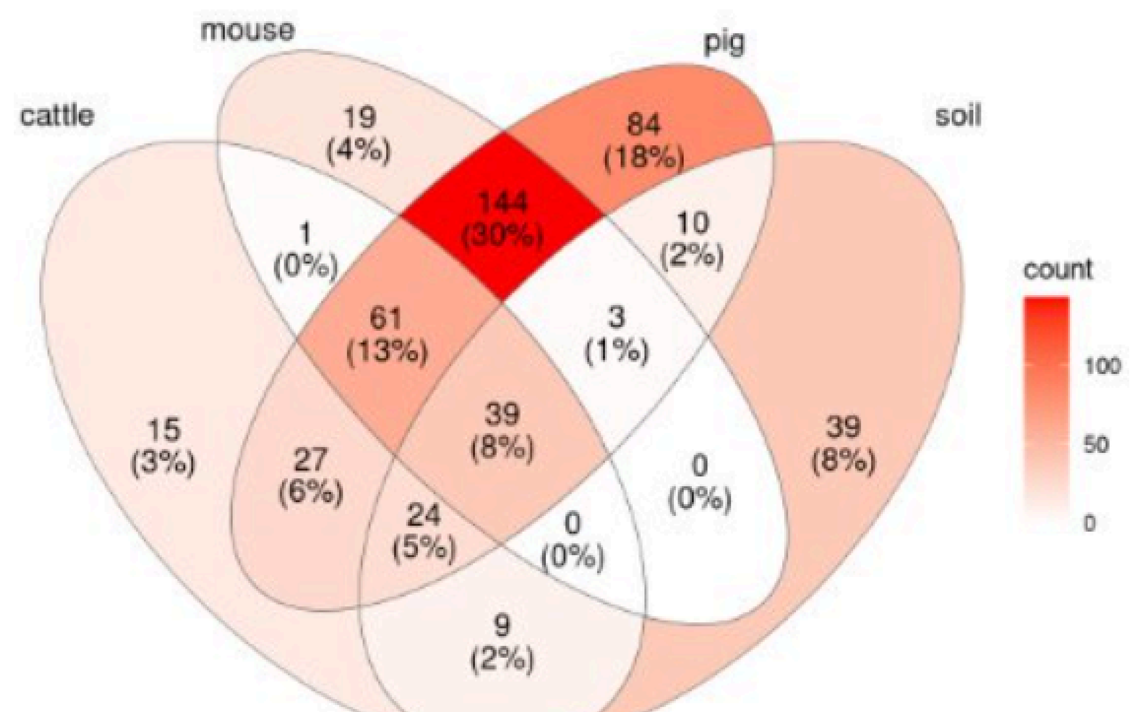


Figure 2 Count of AMR genes shared between each sample type (n=48)

References,He, et al 2020 https://doi.org/10.1038/s41545-020-0051-0 ,World Health Organization, 2014. ISBN: 978 92 4 156474

Estimating the nutrient supply from agriculture in Scotland

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Introduction

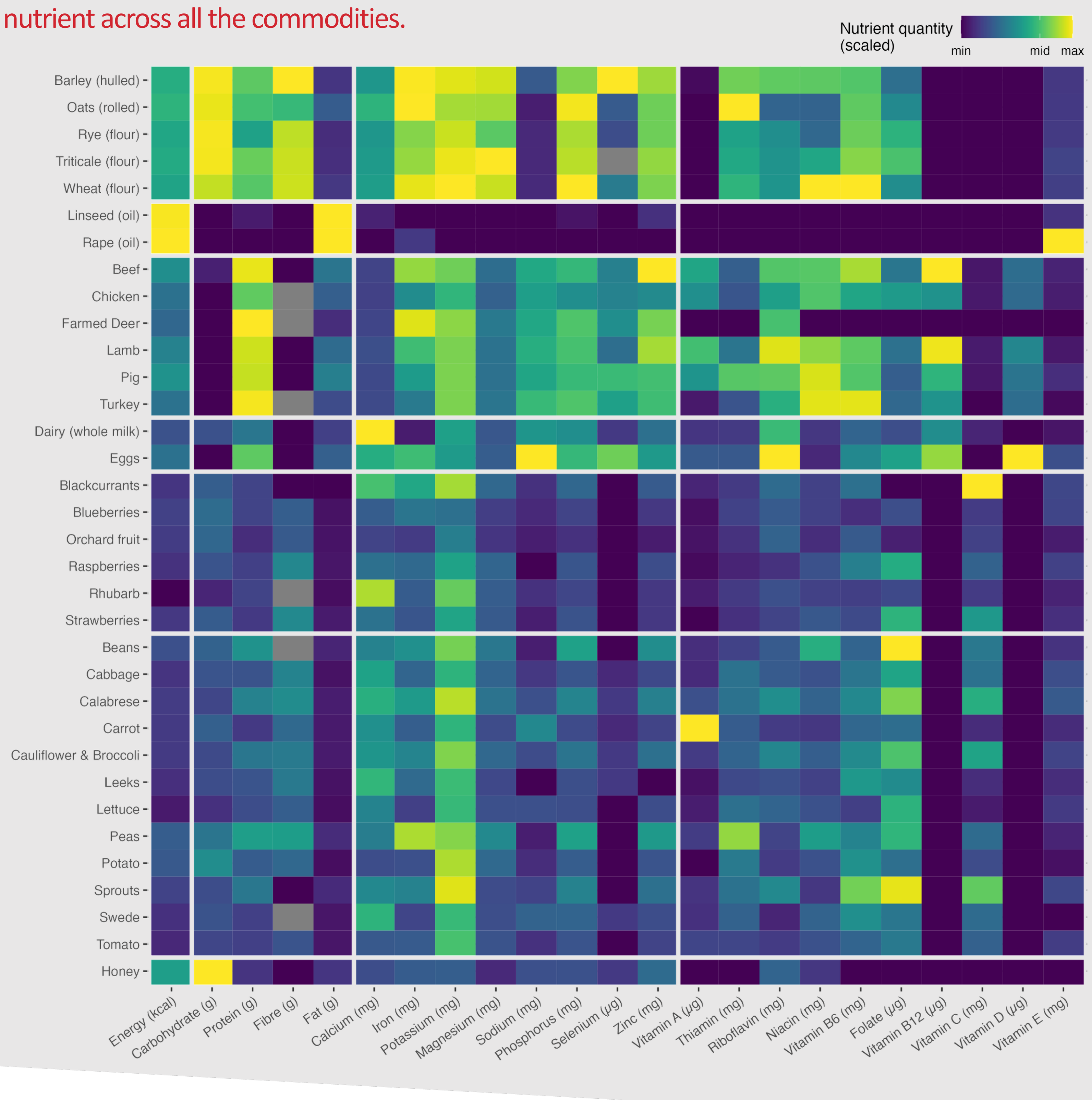
Net Zero targets increase the demand for land and potentially take land out of food production. To support choices about where and what might be produced, we present an estimate of the nutritional value of agricultural commodities produced in Scotland.

Methods

- Agricultural census data were used to identify commodities for human consumption.
- Commodities matched to least processed form of foods.
- Nutrient data for each food were drawn from the UK Composition of Foods Integrated Dataset[1].
- Average yield and production data used to estimate the supply of nutrients up to the farm gate (*i.e.* prior to food processing).

Figure 1 – *Nutrients per 100g of least processed food*

Commodities were matched to the least processed form of their respective food, for example whole flour from wheat. Where appropriate, a weighted average was made of different derived foods, for example averaging across meat, fat and offal. Colours are scaled to show the relative amount of each nutrient across all the commodities.



Results

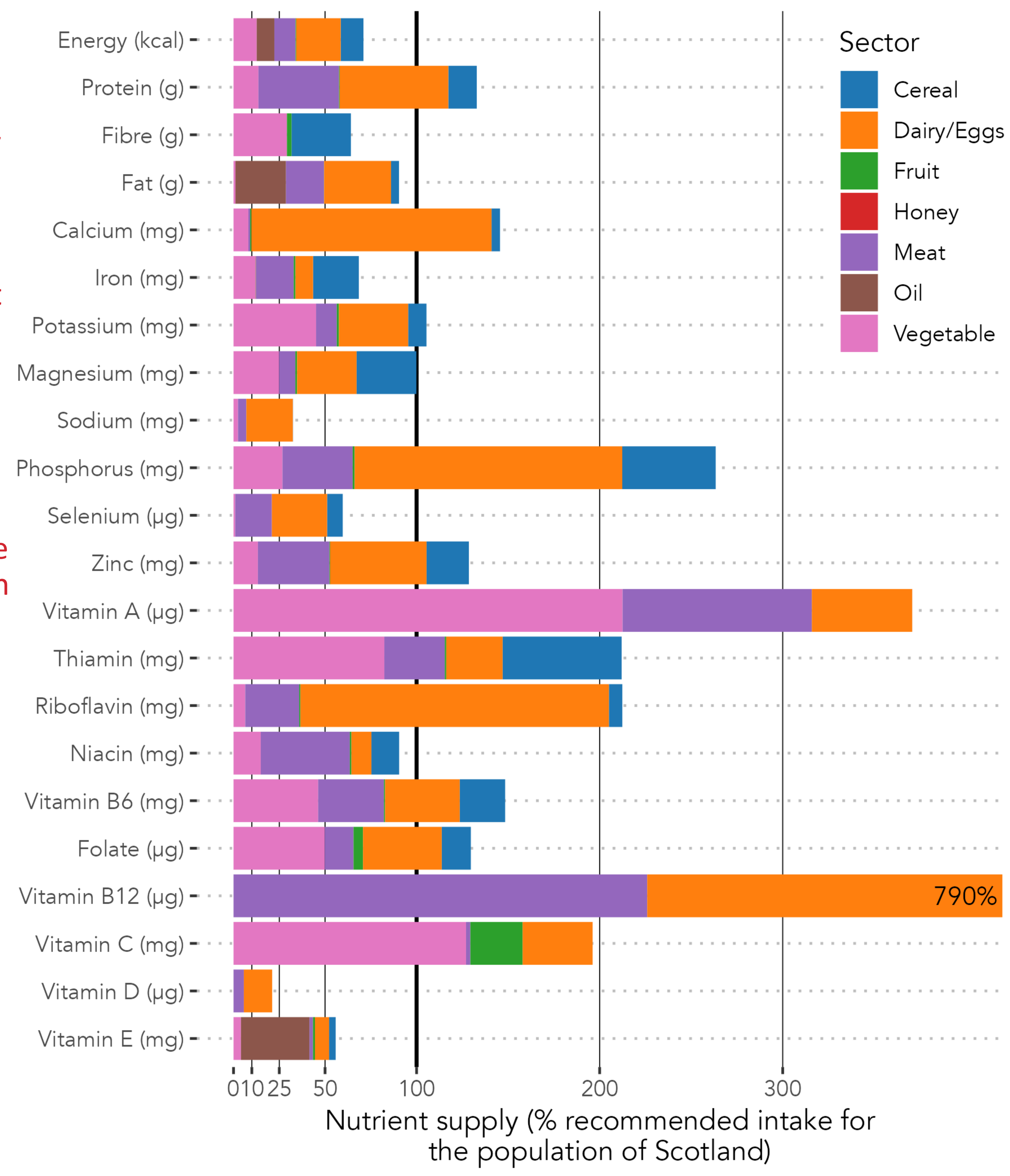
The potential nutrient supply from cereals is not realised because most production in Scotland is not for human consumption.

Considerable land is devoted to ruminant livestock (directly or producing fodder), but their contribution to nutrients is modest.

Milk, potatoes and carrots are produced in large quantities which means they contribute most to the supply of nutrients.

Figure 2 – *Estimated supply of nutrients by agricultural sector relative to population needs*

The theoretical supply of different nutrients, summed across sectors and presented relative to the recommended daily values for the current population of Scotland.



Conclusions

- The nutrient supply from land in Scotland is not always what consumers have access to and the supply of nutrients changes in food processing.
- Understanding the potential and realised nutrient supply from domestic agricultural production helps to evidence a discussion about how agriculture is valued
- Opportunities exist to reimagine food production to maximise the supply of nutrients across Scotland and consider different uses of land.

Acknowledgement

Special thanks go to SEFARI Gateway and RESAS who provided funding through a SEFARI Gateway Fellowship for this work. This study was informed and enhanced by the work of RESAS analysts.

References

[1] https://www.gov.uk/government/publications/composition-of-foods-integrated-dataset-cofid

Changing consumer preferences for single-use cups

Regulation, persuasion, or motivation?

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Introduction

- Single-use disposable cups represent a significant source of single-use plastic because they are used in large quantities and are not easily recycled.
- Switching to reusable cups for takeaway drinks would be an effective way to reduce the environmental impact of this type of packaging.
- The Scottish Government has recently launched a consultation on charging for single-use disposable cups[i].
- This study provides evidence on the effectiveness of charging versus other measures.

Research Questions

- How effective is a charge compared to a discount and how do different types of consumer respond?
- Which type of reusable cup do consumers prefer?
- Does raising awareness help?
- What motivations are associated with higher reusable cup use?

Methods

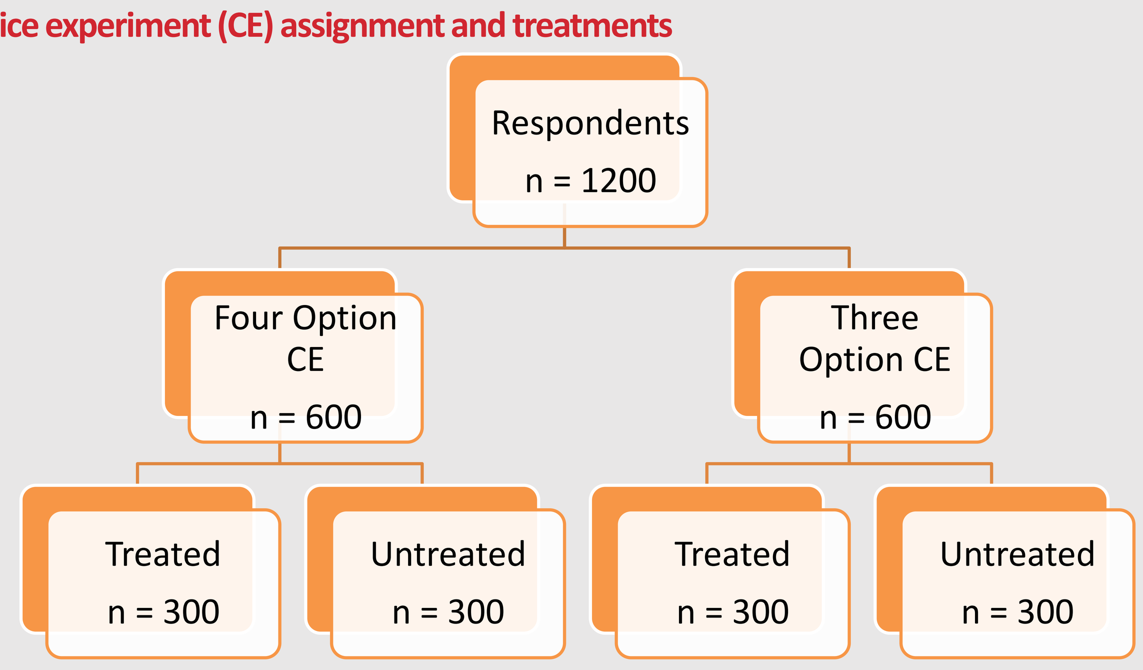
We conducted a choice experiment with a representative sample (age, gender, employment) of 1200 Scottish consumers who regularly purchase non-alcoholic drinks in takeaway cups. Table 1 shows an example choice card. In addition to participating in the choice experiment respondents were asked about their current takeaway drink purchasing habits, level of environmental concern, confidence in their own ability to make a switch to reusable cups as well as the perceived advantages and disadvantages of different cup types. Respondents were randomly assigned to two experimental and treatment conditions (Figure 1).

Table 1 – Example Choice Experiment Card Offering Four Options

Attributes	Level
Cup Type	Single-Use, Returnable, Refillable
Charge	£0, £0.15, £0.25, £0.35, £0.45
Discount	£0, £0.15, £0.25, £0.35, £0.45
Scheme	Deposit paid upfront, Charge for none return

Returnable cups are owned by the shop and borrowed by you. You return it to the shop after use. The shop is responsible for washing and sanitising the cup. It may then be used by other people. **Refillable cups** are owned by you, and you take it to the shop to fill up. You keep it after use. You are responsible for washing and sanitising the cup. Only you use this cup

Figure 1 – Choice experiment (CE) assignment and treatments



Results

We found that when four options were offered (disposable, refillable, returnable plus opt out), **a charge of around 25 pence reduced the likelihood of single-use disposable cup selection by 50% with all other attributes held at baseline level while a discount of nearly £1 was required to achieve the same effect (Figure 2)**.

Figure 2 – Simulated probability of selecting a disposable, refillable or returnable cup based on our model at different charge and discount levels

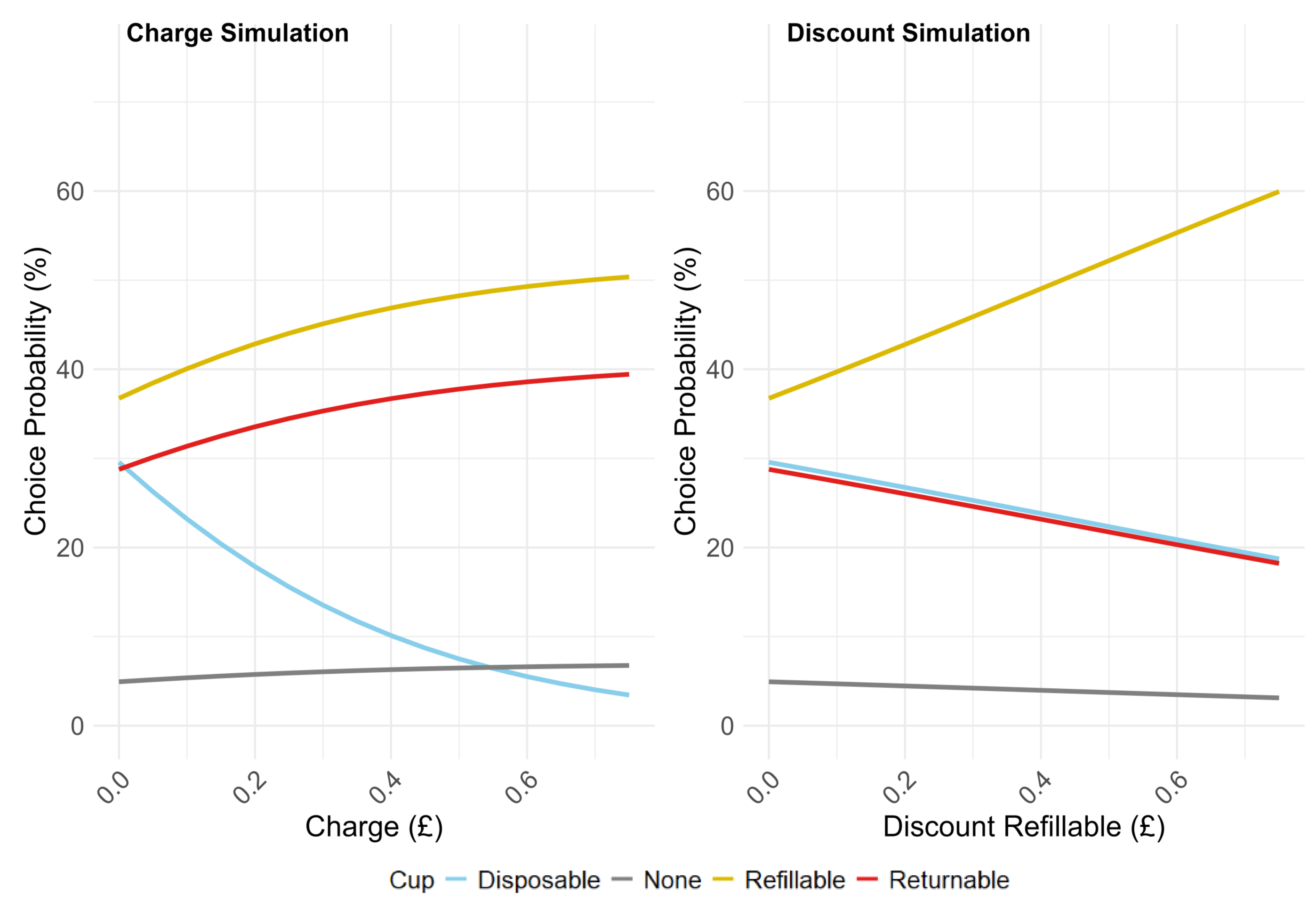
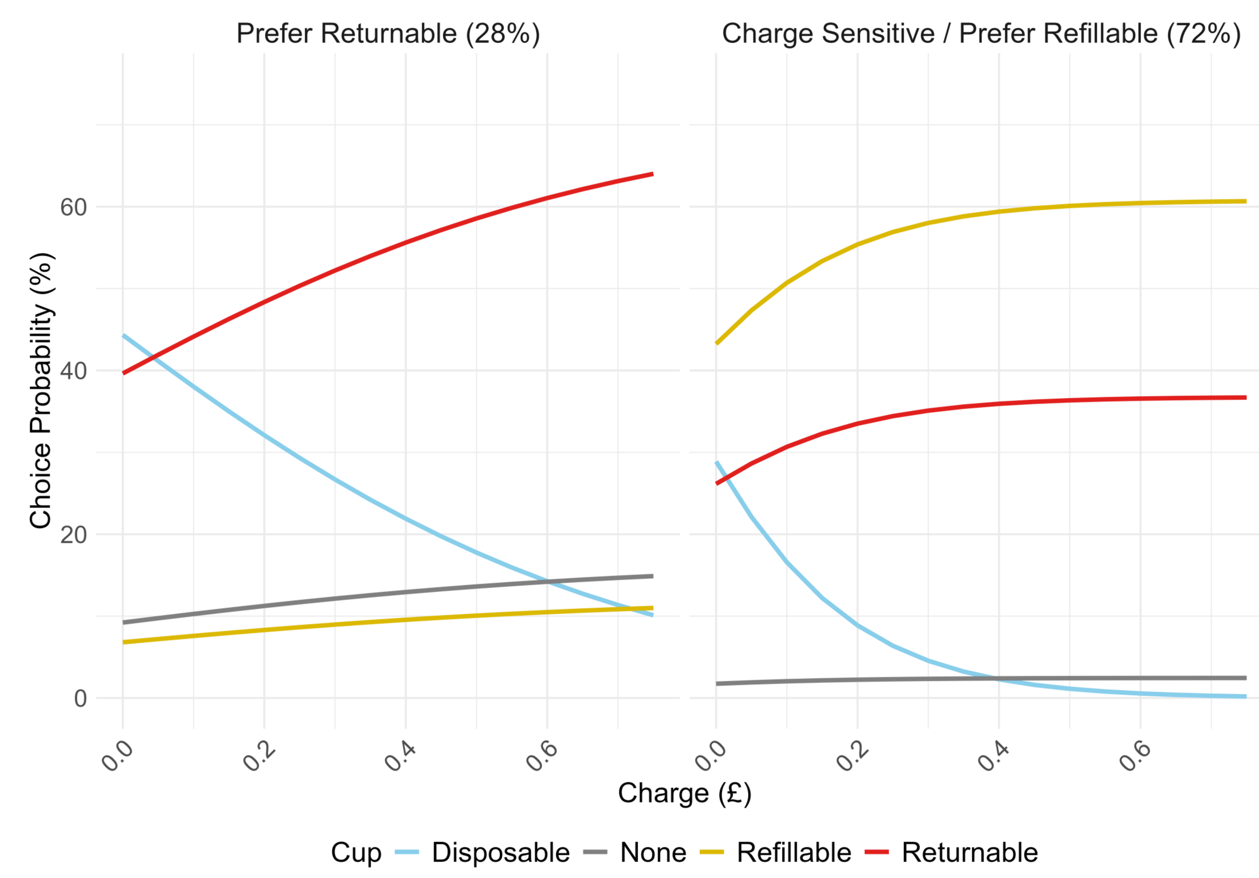


Figure 3 – Simulated probability of selecting a disposable, refillable or returnable cup at different charge levels by consumer group



Follow link for interactive models

Conclusions

- **Charges were around four times more effective than discounts at increasing reusable cup selection.**
- **Most consumers preferred refillable cups to returnable cups, but a notable segment prefer returnable therefore offering them could support behaviour change (Figure 3).**
- **We did not detect a significant effect for the environmental impact awareness raising treatment.**
- **Consumers, vary in their sensitivity to charges and underlying preferences for reusable cup type. Notable associations with age and current behaviour.**
- **Practical rather than motivational or informational support is key to supporting this behaviour change.**

Acknowledgement

This project was funded under "Building the circular economy: sustainable technologies, green skills and upscaling behaviours – C4" part of the Scottish Government's Environment Natural Resources and Agriculture Strategi Research Programme 2022-27. Special thanks go to Robert McMorran and Tom Collins at RESAS for their input to the study design and survey.

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Place-based community resilience to water vulnerabilities

Case study analysis of community-based action in remote coastal communities

Carly Maynard[1], Hannah Grist[1], Kate Lamont[1]
1. Scotland's Rural College

Scottish Government's Environment, Natural Resources and Agriculture Programme:
Science Evidence and Policy Conference, September 2024, Edinburgh

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Introduction

Scotland faces multiple and increasing **water-related challenges such as coastal, fluvial and pluvial flooding, poor water quality, ageing supply systems, changing precipitation patterns and supply limitations**. Climate change is set to compound many of these issues through increased average air temperatures, hotter, drier summers and more extreme weather events[1]. Indirect impacts associated with these changes include challenges for food production, restrictions on house-building and population shifts. Remote coastal areas are unique in that they face the land-based pressures with the additional changes brought about by rising sea levels and risk of erosion, saline intrusion, etc. Additionally, they often rely on internal, community-led structures to address risks and to build resilience. The 2023-24 Programme for Government[2] and the National Performance Framework[3] highlight water and climate issues as priorities for adaptation.

This study aimed to examine examples of what some communities are already doing to address these risks and to provide recommendations of good practice and suggestions for supporting community resilience building.

Methods

Case study analysis was used to explore the situations, challenges and actions for five remote coastal communities in Scotland, in relation to water-based vulnerabilities. Communities were selected based on location, presence of at least one water-related challenge, availability of multiple participants with an aim to providing varied perspectives and a desire from the community to take part.

Interviews were conducted with **26 participants** across the five case studies, as well as **document analysis** where appropriate to provide contextualisation. Interviews took place between June and December 2023 and included **online, in-person and walking interviews** (selecting the method most suitable for each participant). **Grounded theory and thematic analysis** were used to draw out key themes in relation to experiences, actions, limiting factors, outcomes and lessons learned. Case studies were carried out in: **Luing; Tiree; Mull; Skye and Knoydart.**

Results

Most communities faced multiple issues e.g. increasing coastal flood risk plus ageing water supply infrastructure. Commonality existed between communities in terms of the types of problems faced, but varying contexts dictated that each community experienced those problems differently, meaning methods for dealing with issues varied by community.

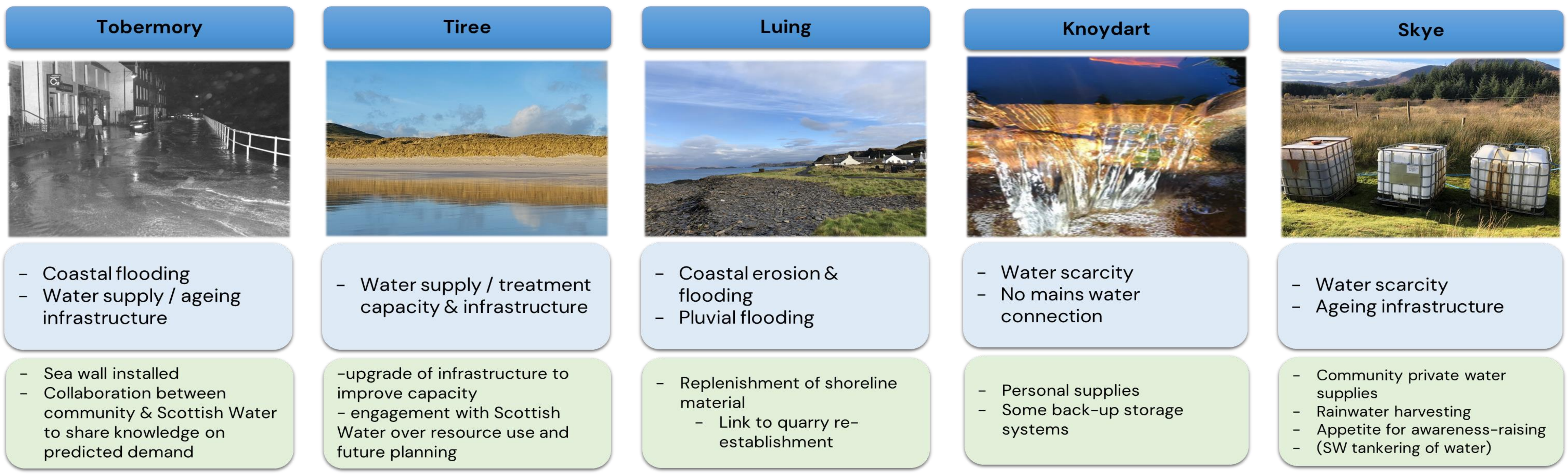

Figure 1 Summary of key issues and responses in the five case study areas

Key themes

- Strong sense of self-sufficiency linked to rural living
- Multiple links between water-related risks and other areas of community development: housing, economic development, population stability, growth
- Accepted need to utilise multiple forms of knowledge to reach all stakeholders
- Small / rural communities deal with risks in different ways to larger, more connected communities
- Use of social capital is key to many successes in remote and rural communities

Challenges

- Many of the challenges / barriers faced were linked to availability or conditions of funding
- Maintaining and utilising social capital (e.g. in the form of community organisations) is difficult and needs to be actively managed e.g. by investing in inter-generational skills transfer
- Rural communities with less social capital struggle more with community development
- Lack of broader institutional support can stall development / resilience work

Conclusions

Small and rural coastal communities face a multiplicity of water-related challenges which do not exist in isolation but are intricately related to other elements of development.

Key recommendations from the study include:

- Addressing water-related issues to **unlock other rural development challenges** e.g. re-population
- If engagement needs to be encouraged, make water-related challenges **relevant and tangible**
- Ensure messaging, management approaches and policy are **place-based or adaptable** enough to be relevant to remote coastal communities
- Make community action more **accessible** to a wider range of demographics e.g. by facilitating skills transfer, simplifying proposal processes, making space for flexible forms of engagement
- Utilise **social learning** by supporting sharing of experiences and knowledge between communities
- Account for different knowledge types to make engagement accessible and far-reaching
- **Utilise collective knowledge** e.g. via umbrella organisations or community champions

Acknowledgement

With thanks to all the individuals and communities who engaged as participants in this research for sharing their experiences and knowledge and welcoming us to their communities. Thanks also to our steering group who helped formulate appropriate questions and ensure relevant focus on the topic.

This work was funded by the Strategic Research Programme 2022-27, Scottish Government Rural and Environment Science and Analytical Services Division.

References

1. Adaptation Scotland, March 2024, Climate Projections for Scotland.
2. Scottish Government Programme for Government 2023-24.
3. Scotland's National Performance Framework.

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RESAS
Rural & Environmental Science and Analytical Services

Scottish Government
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Novel tests to detect coliphages in drinking water

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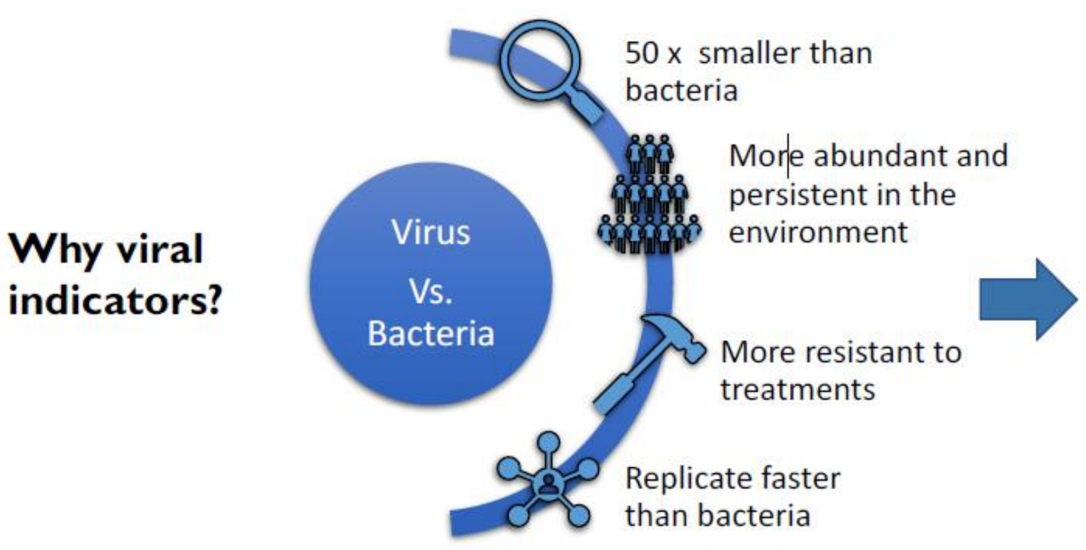
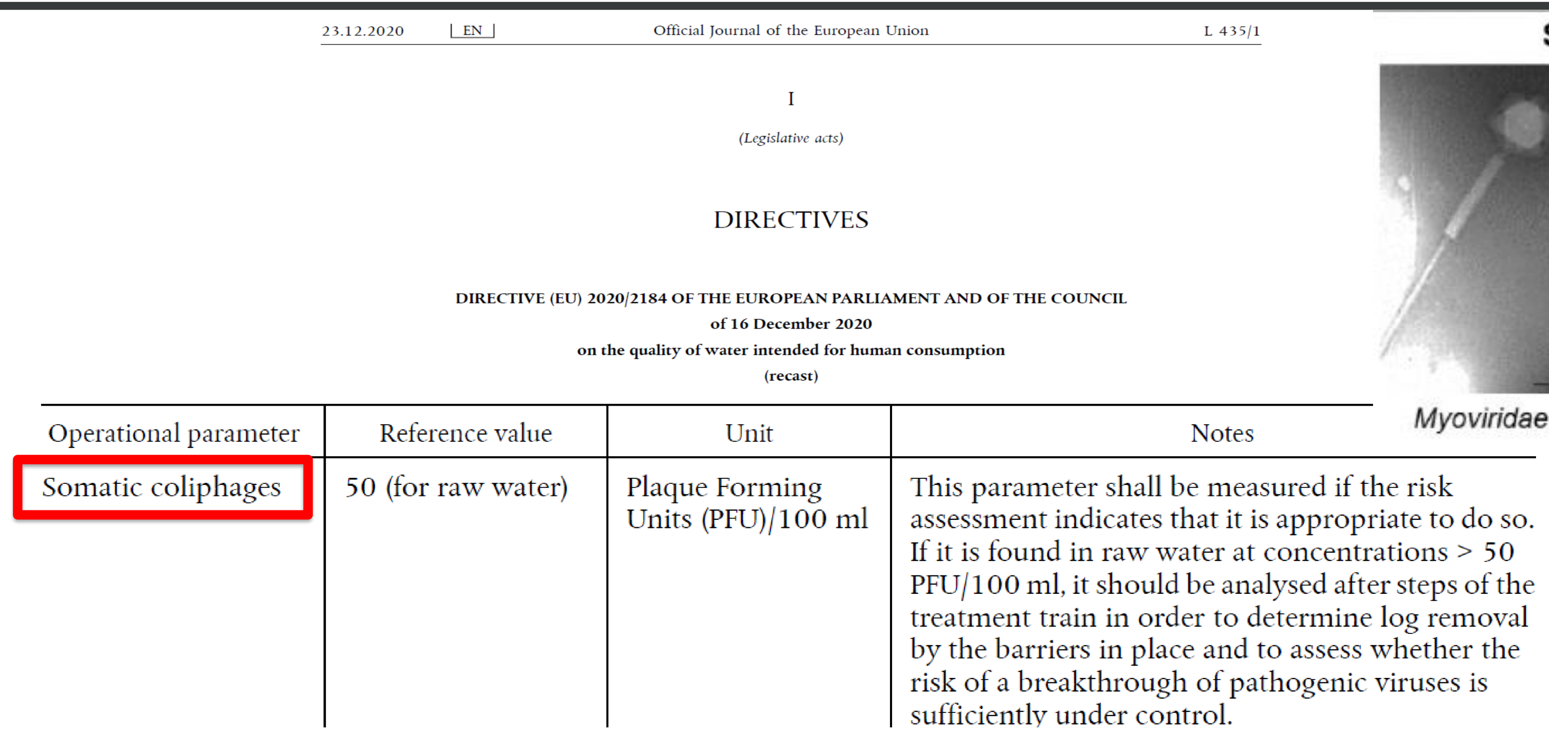
Background

Bacteriophages (phages) are viruses that infect bacteria and are the most widely distributed and abundant biological form on Earth, estimated at ~ 10^{31} particles in the biosphere. Bacteriophages that infect coliform bacteria are known as coliphages, and their survival and incidence in water environments resemble those of human viruses more closely than most commonly used bacterial indicator. Therefore, they have been proposed as good water quality indicators. On January 2021, the recast Drinking Water Directive 98/83/EC established somatic coliphages as a new indicator required for operational monitoring of the drinking water treatment process. Culture-based detection and enumeration of coliphages takes an average of 18 to 24 hours to yield results.

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I

(Legislative acts)

DIRECTIVES

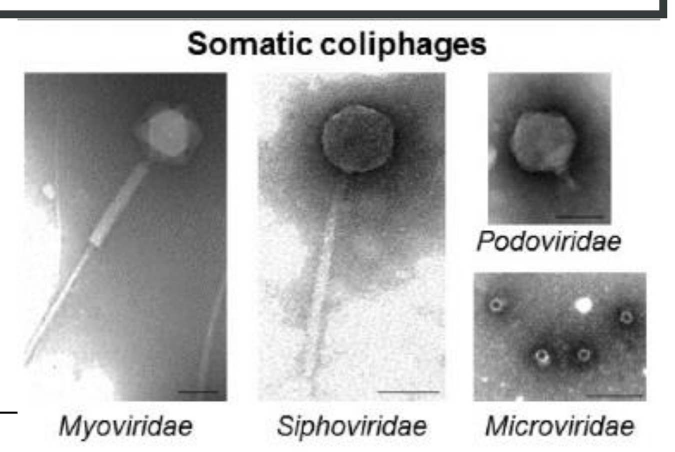
DIRECTIVE (EU) 2020/2184 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 16 December 2020

on the quality of water intended for human consumption

(recast)

Operational parameter	Reference value	Unit	Notes
Somatic coliphages	50 (for raw water)	Plaque Forming Units (PFU)/100 ml	This parameter shall be measured if the risk assessment indicates that it is appropriate to do so. If it is found in raw water at concentrations > 50 PFU/100 ml, it should be analysed after steps of the treatment train in order to determine log removal by the barriers in place and to assess whether the risk of a breakthrough of pathogenic viruses is sufficiently under control.



Current methods for detection and enumeration of somatic coliphages

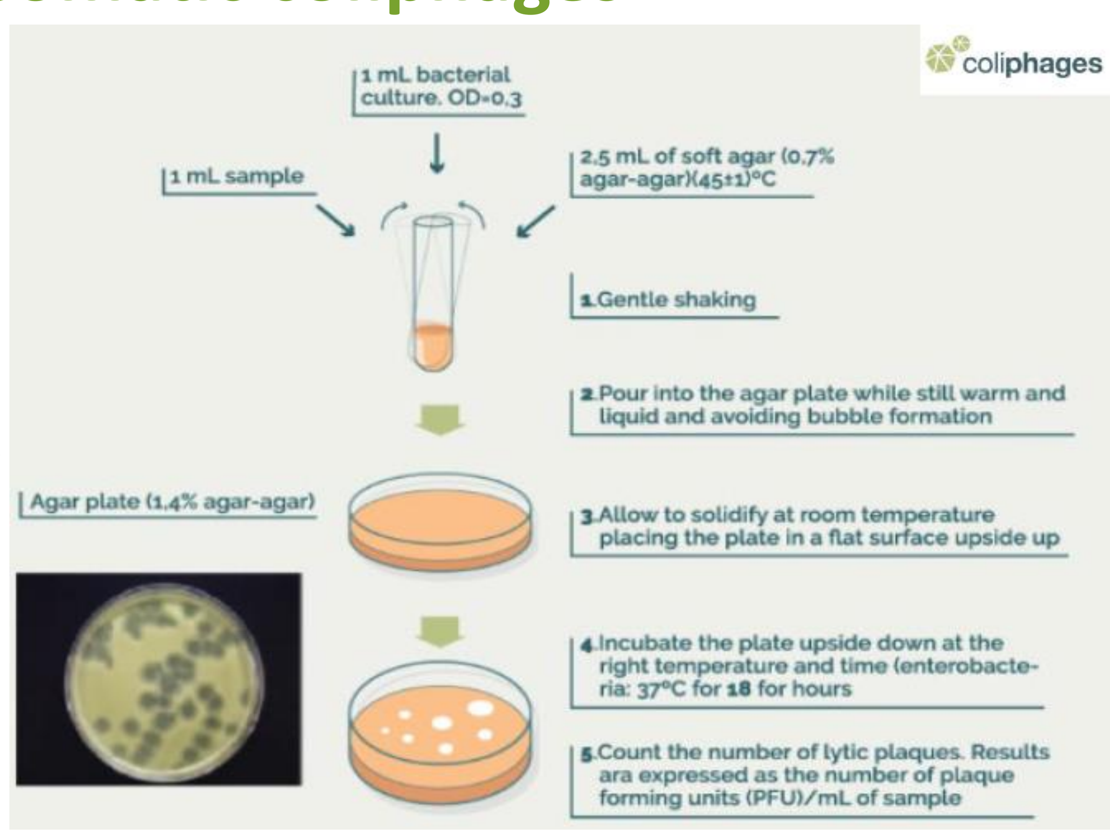
International Standardization Office. ISO

10705-1: 2002. Water quality. Detection and enumeration of bacteriophages.
Part 1: Enumeration of F-specific RNA bacteriophages

10705-2: 2002. Water quality. Detection and enumeration of bacteriophages.
Part 2. **Enumeration of somatic coliphages**

10705-3: 2003. Water quality. Detection and enumeration of bacteriophages.
Part 3: Validation of methods for **concentration** of bacteriophages **from water**

10705-4: 2001. Water quality. Detection and enumeration of bacteriophages.
Part 4. Enumeration of **bacteriophages infecting** ***Bacteroides fragilis***



Applying Standard methods still > 16 h

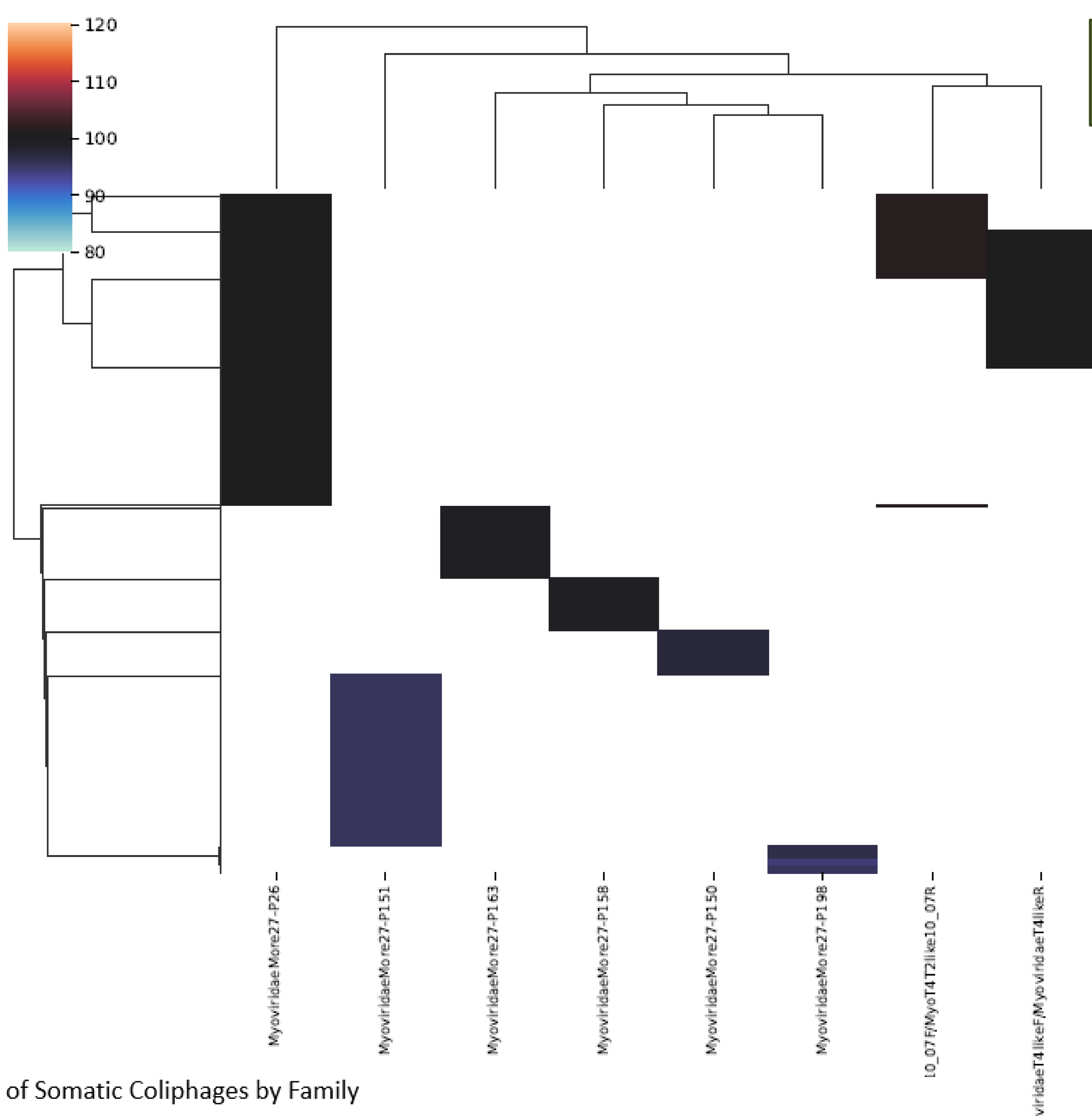
Purpose:
Develop a novel molecular method to detect somatic coliphages in drinking water faster than standard methods

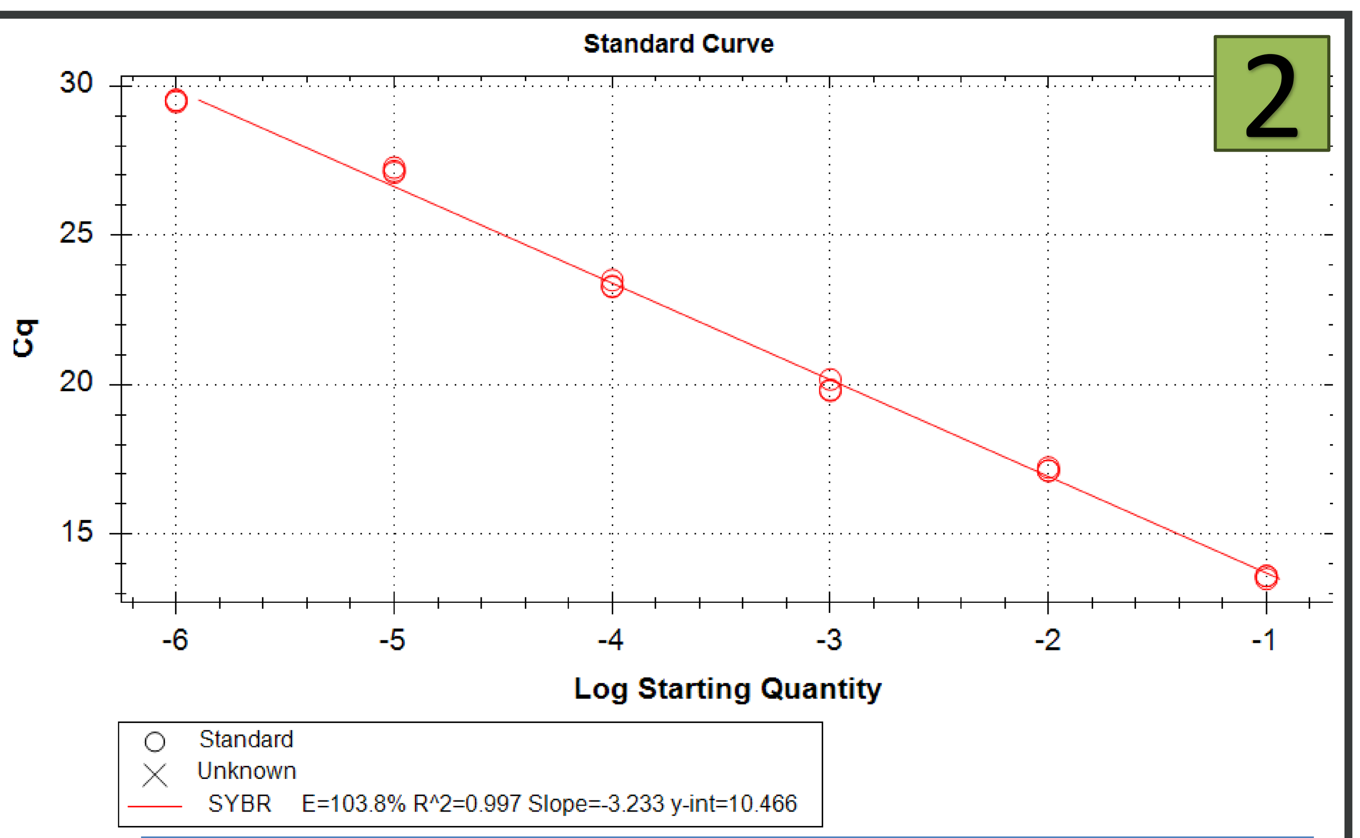
Material and Methods

Phase 1:Bioinformatics
Full genome sequence alignment
Family specific primer approach
Primer design
In silico PCR

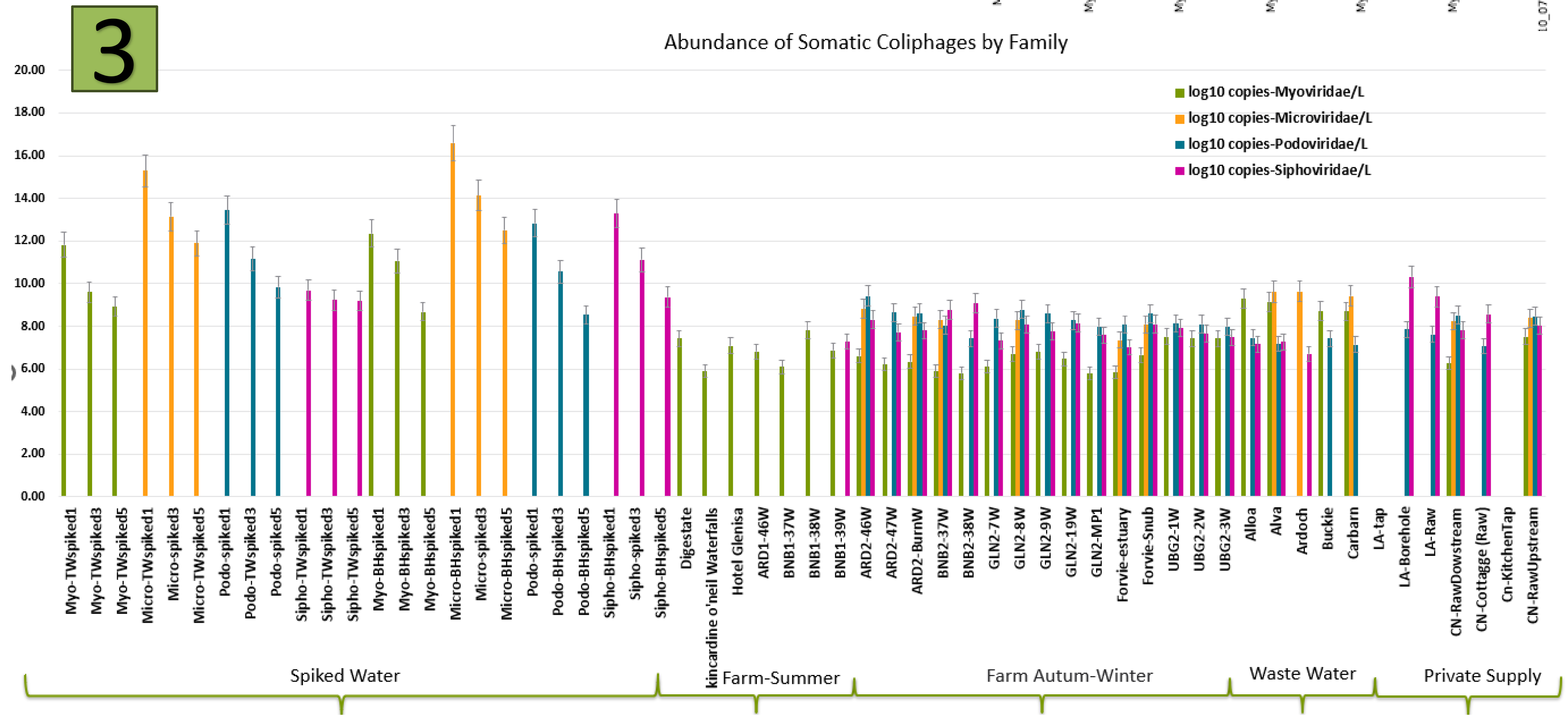
Phase 2:Method Validation
In vivo PCR
Standards Development
Method Validation: Efficiency, specificity, LOD, LOQ

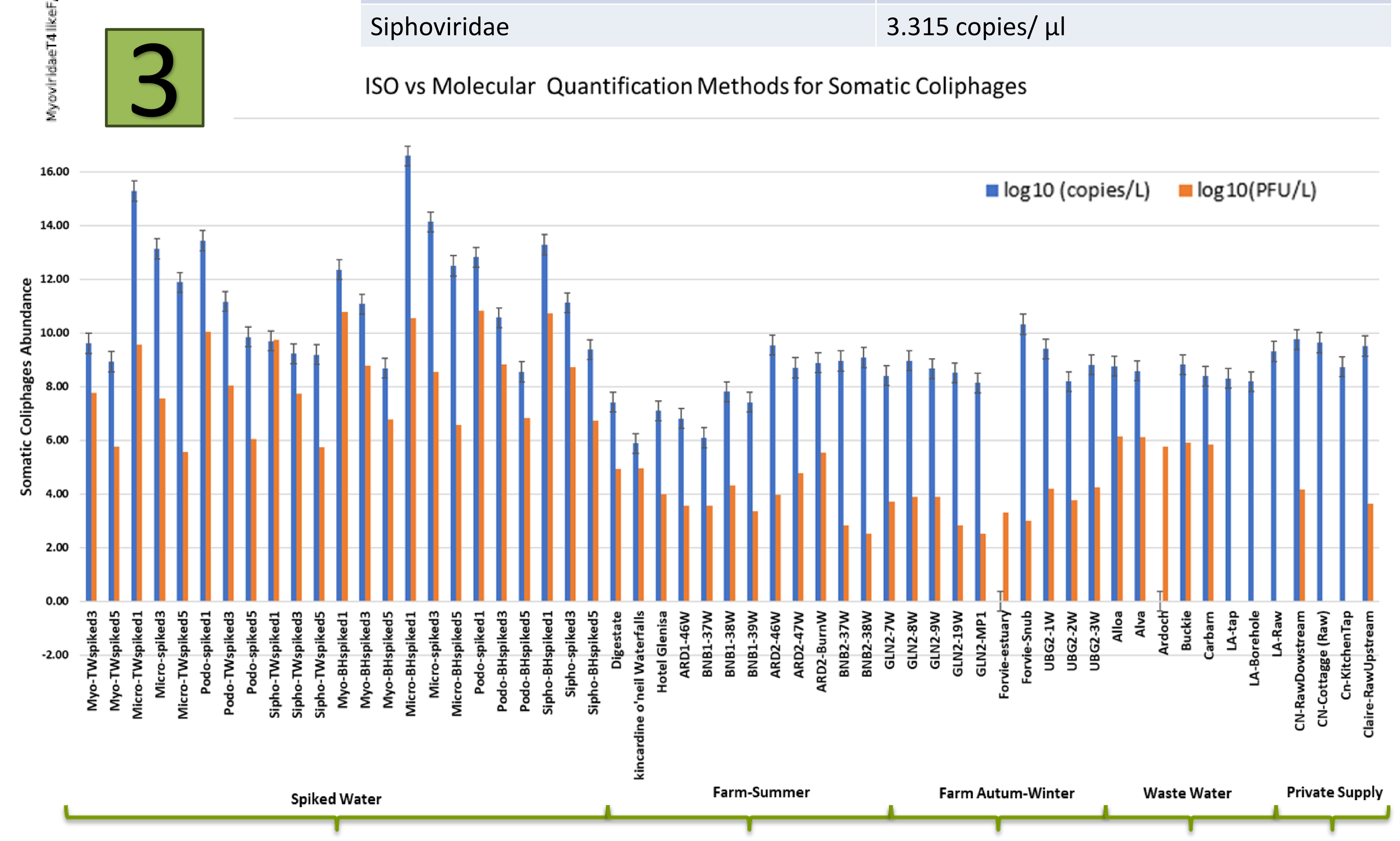
Phase 3:Environmental samples testing
Application of molecular method on environmental samples
Comparison of results with ISO Method





METHOD VALIDATION PARAMETERS	
Efficiency	90-110%
R2 (Coeff. Of determination)	0.993-0.997
Myoviridae	10.4 copies/ µl
Microviridae	2.69 copies/ µl
Podoviridae	26.5 copies/ µl
Siphoviridae	3.315 copies/ µl





Results

Development of a molecular method to detect somatic coliphages in drinking water
8 hours protocol
Cost effective
Detects somatic coliphages by family

Future Work

Workshop to train stakeholders in molecular method application
Use of the method to map somatic coliphages in Scottish catchments , feed current quality indicators models, produce outbreak predictions, and develop management recommendations.

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Careers and skills for a future climate

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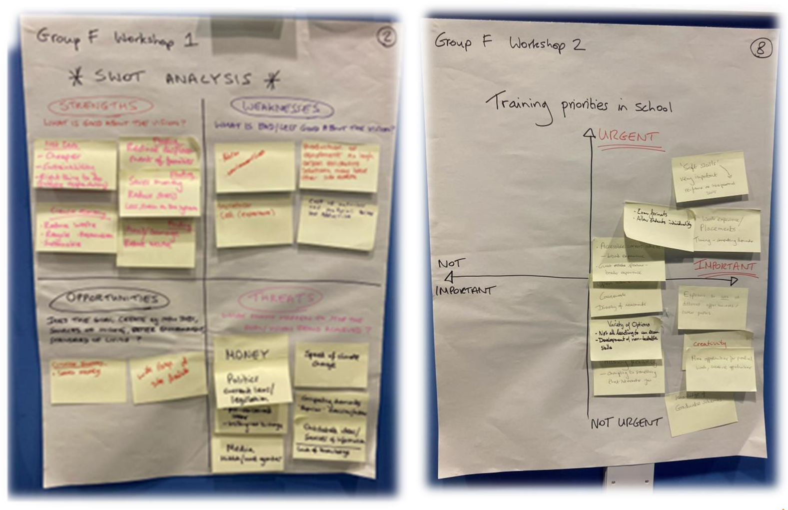
SEFARI LEADING IDEAS FOR BETTER LIVES

Introduction

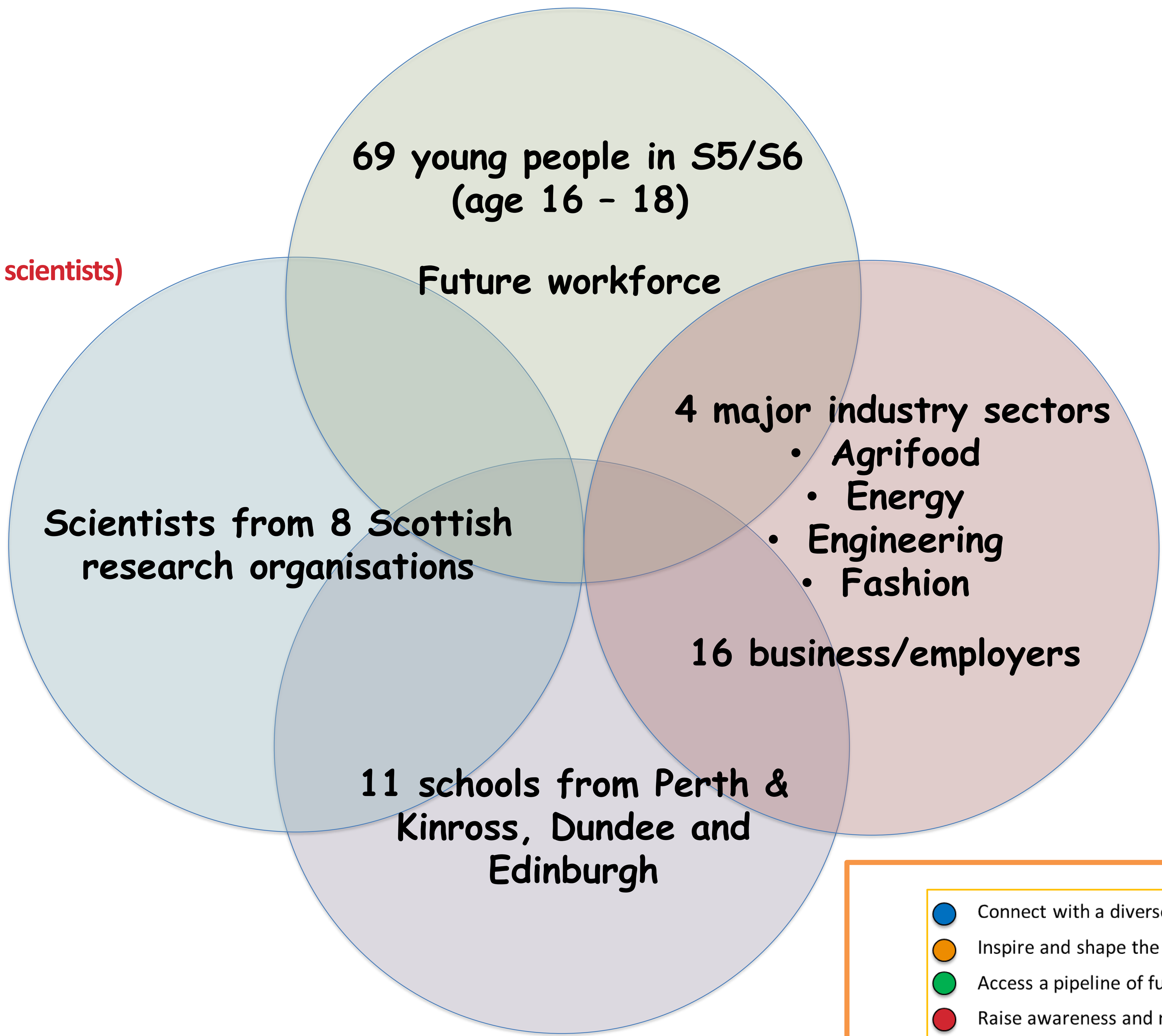
- The urgent need for climate-resilient communities and economy poses fundamental questions about the **role and mission of both research and education**.
- A **novel multi-actor and multi-generational model for knowledge exchange** was designed and piloted to give young people - the future workforce - agency in **co-designing**, with research and industry, the pathways to climate resilience and identify the necessary **skills and jobs underpinning climate transition**
- Collaborative approach to:
  - **break** down barriers between silos in research, education and industry
  - **empower** young people
  - **inspire** action (and avoid apathy)

Challenges and visions for climate transitions (research scientists)

Muli-actor/generational participatory workshop



Collaborative analysis and discussion



Young people feedback

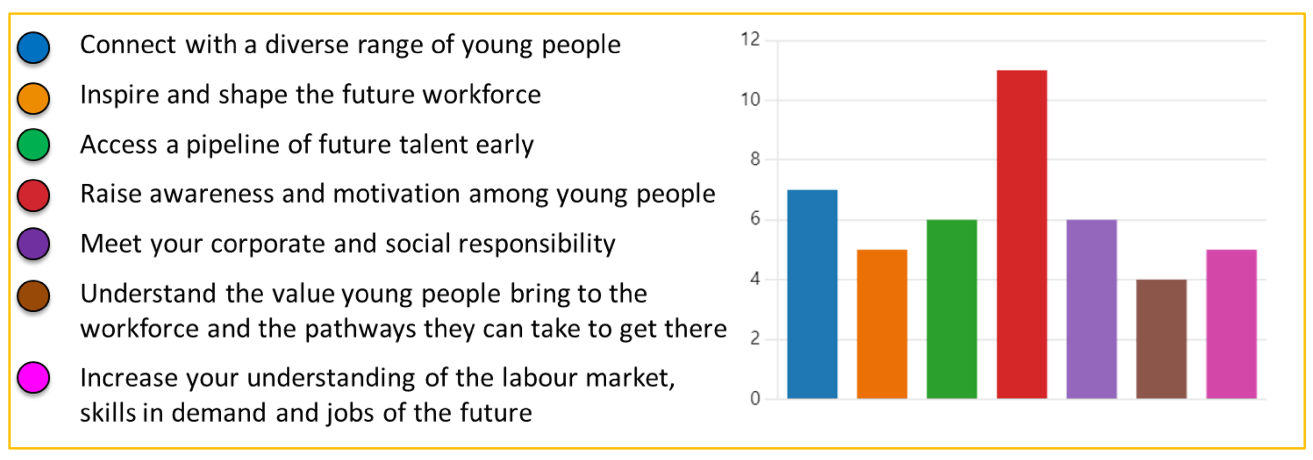
One word describing how I feel about today (day of the event) is..

Before the event...

Nervous, Day off school, Anxious, Cautious, exited, Crazyyy, Buzzing, Interested, good, Scrumptious, intrigued, neutral, Hyped

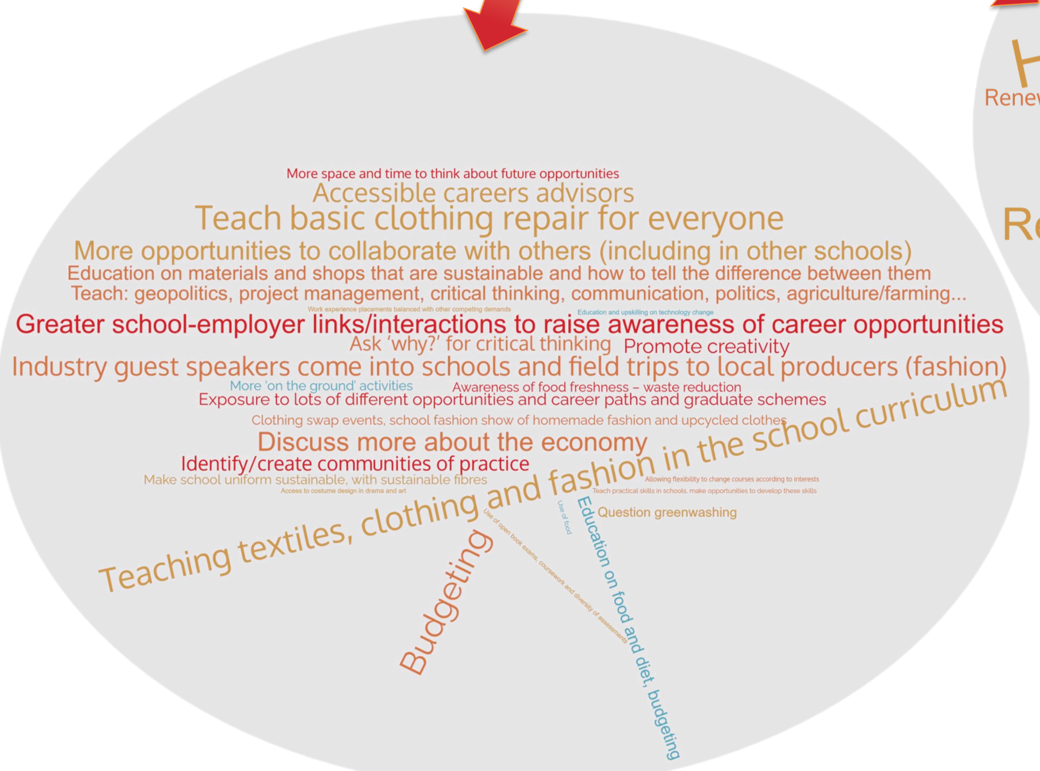
After the event...

Informed, Experienced, climate solutions, environment, Excited, Enlightened, Hopeful, Interested, solutions rather than anxiety, Optimistic, Interesting, neutral, Happy, fun



Responses of business and industry workshop participants to the survey question *"Participating in this activity has helped me to:"*

Young people's recommendations for policy



Young people's recommendations for the education system

To know more about this project....

Read our blog | **Listen to our podcast**

Acknowledgements

This unique model for KE was only possible thanks to the support from SEFARI INNOVATIVE KNOWLEDGE EXCHANGE FUND and the contributes from Morgan McLeod (DYW), Christina Couser (Bertha Park), Esther Jones, Katharine Whyte (BioSS), Wendy Russell (The Rowett Institute), Eleanor Treadwell, Nikki Dodd (CREW), Nicola Dunn, Anne Marte Bergseng, Kate Symons, Ines Crespo (ClimateXChange) Liz Dinnie, Carolyn Mitchell, Mike Rivington (The James Hutton Institute), Meg Bartholmew (Heriot-Watt University), Ewan Edwards (Xodus environmental consultancy), Rwayda Al Hamd (Abertay University), Lynn Wilson (Circular Design Consultancy)

What can help Scotland shift to sustainable diets?

1495 UNIVERSITY OF ABERDEEN
The Rowett Institute

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1 The Rowett Institute, University of Aberdeen; 2 BioSS

email: d.mcbey@abdn.ac.uk

Introduction

- Meat is often consumed in quantities that are unhealthy and environmentally damaging.
- To achieve sustainable diets, the UK Climate Change Committee propose a 20% reduction of meat consumption by 2030.
- We explore attitudes to meat consumption and how these relate to potential policies that might encourage a shift to more sustainable diets.

Methods

- Online survey of 1,590 adults in Scotland.
- Questions on attitudes and intentions.
- Rank polices based on whether they would impact their behaviour.
- Latent class model to group people by their responses to the questions around capability, opportunities and motivations.
- Typologies used to compare preferences for interventions.

Results

Attitudes to reducing meat consumption

- Meat-eaters (95%, n=1504) divided into four groups: unwilling (14%), ambivalent (25%), willing (45%) and active (16%) (Table 1).
- Motivation is the largest limiting factor to reducing meat consumption (Fig 1).

Ranking policies to encourage change (Fig 2)

- BEST: Cost interventions would likely encourage reduced meat consumption.
- WORST: Information, e.g., messaging, labelling, or endorsement.

Table 1: Attitude to meat reduction

	Unwilling	Ambivalent	Willing	Active
% of respondents	14	25	45	16
% Planning meat reduction in next 3months	13	24	44	49
Days meat eaten last week (mean)	5.5	4.8	5.2	4.6

Fig 1: Capability, Opportunity & Motivation to change meat consumption behaviour

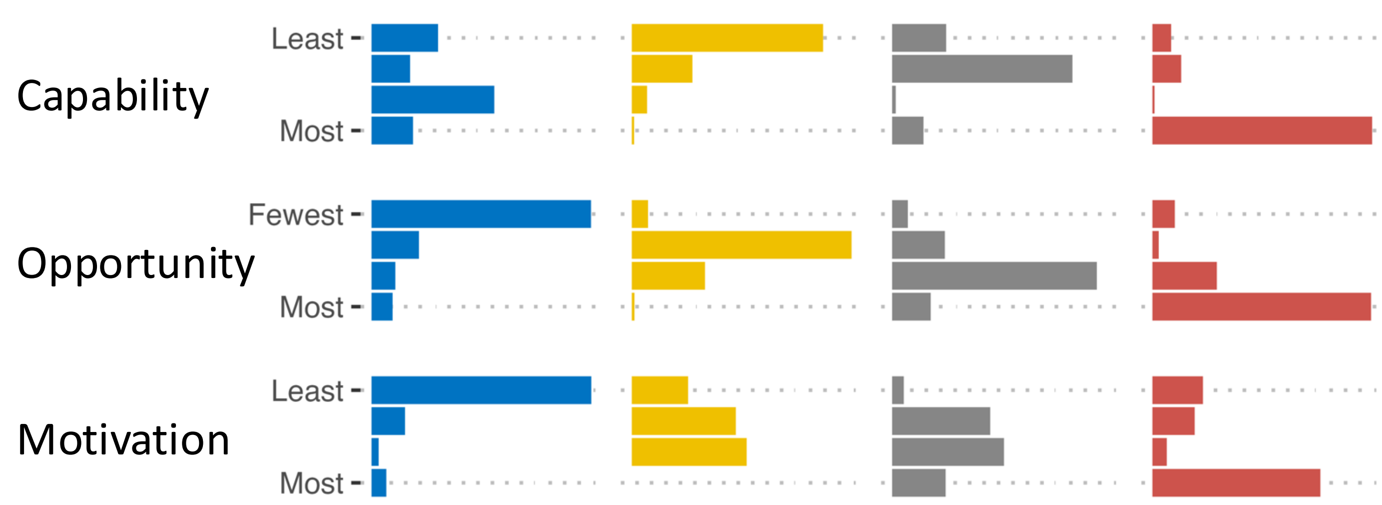
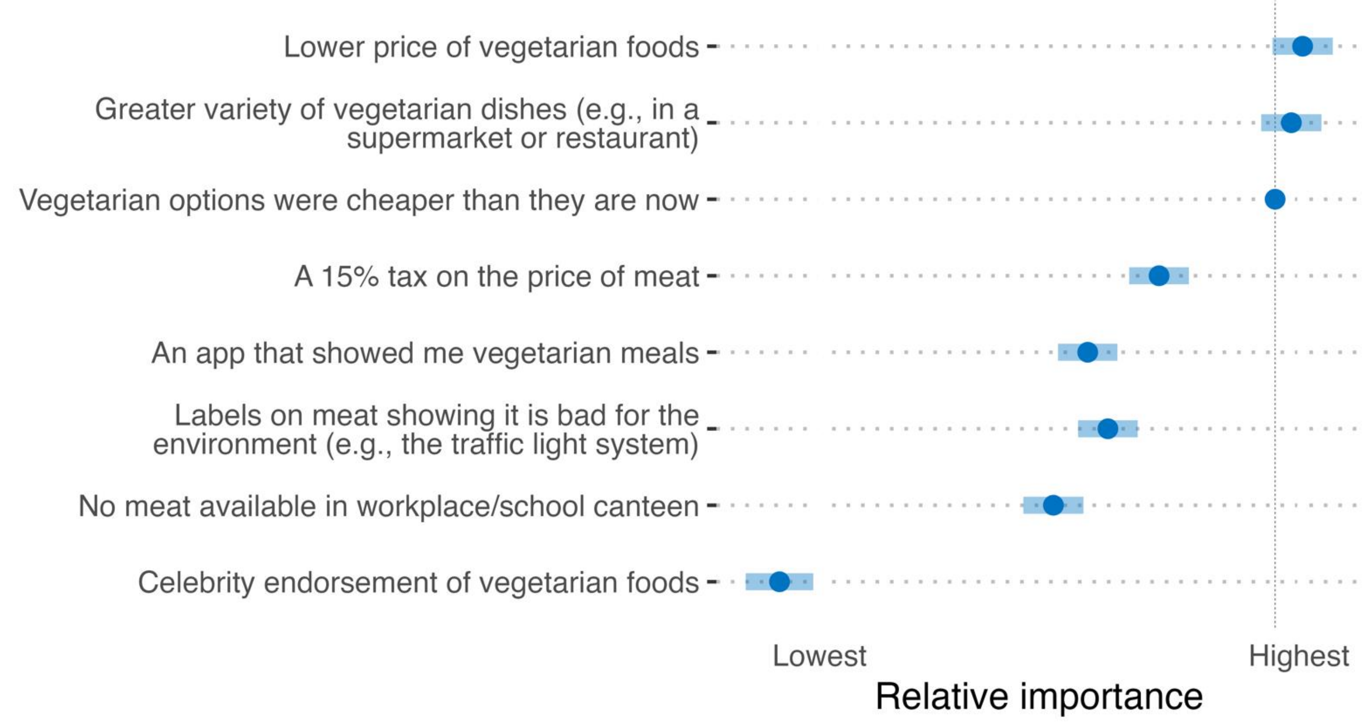


Fig 2: Example policies ranked by perceived effectiveness to reduce meat consumption (shown relative to cheaper vegetarian options)



Conclusions

- Optimism that people are open to reducing meat.
- The difference in days of meat consumption per week between groups was small.
- It may take substantial interventions, typically around pricing, to overcome the motivational barriers to eating more sustainable diets.
- Targeting policies may balance the number of people and size of any reduction in consumption.

Funded by the Scottish Government's RESAS Strategic Research Programme (RI-B5-09)

www.abdn.ac.uk/rowett/

Assessing disease risks in changing environments: Greylag geese as an exemplar study

Moredun
www.moredun.org.uk

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Background

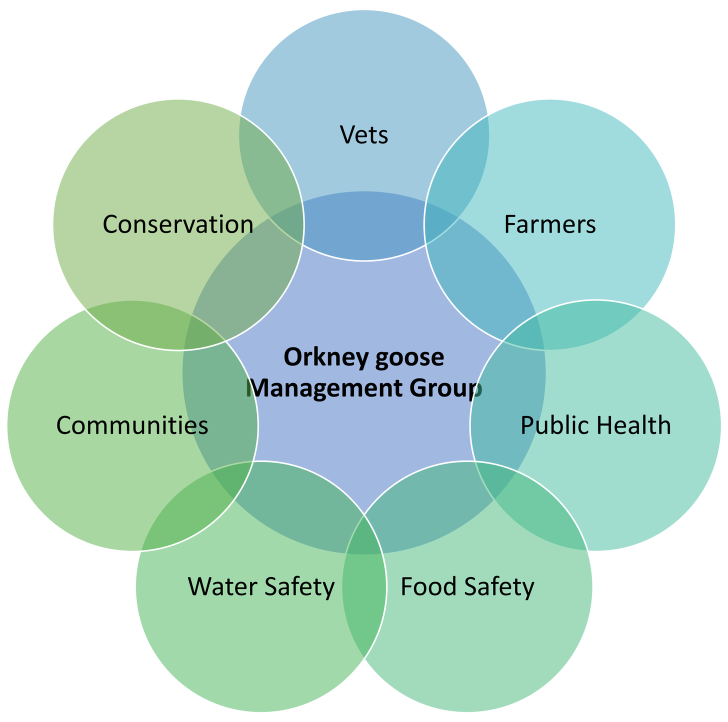
- Climate-driven environmental changes can significantly affect the levels and distribution of microbial pathogens and the hosts that carry them.
- To better understand these risks, robust, sensitive methods for pathogen detection and accessible approaches to sample wildlife carriers and ecosystems are required.
- Populations of Greylag geese (*Anser anser*) in Scotland (migratory and resident) have rapidly increased in size over the last 30 years
- In Orkney, an estimated 20,000 geese are "resident" and a further 40,000 geese arrive from Iceland during the winter months.
- This significant change in **biodiversity** is thought to be driven by **climate change**.
- Due to the resultant widespread faecal contamination of pastures and water, we are investigating microbial risks associated with goose faecal material (MRI-D4-2).

One Health approaches are key to understanding the spread and emergence of zoonotic pathogens and antimicrobial resistant bacteria within different environments.

This requires a range of methodologies to be used in combination to investigate **microbial, host and environmental factors**.

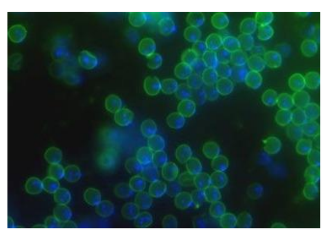
For **migratory birds**, pathogen carriage in breeding and migratory sites must be considered.

Engagement with a wide stakeholder group is key for appropriate experimental design, data interpretation and impact.



Detection of pathogens and antimicrobial resistance

We are investigating the transmission of microbial pathogens between geese, cattle and calves.



- ***Cryptosporidium*** is a gastrointestinal parasite responsible for causing diarrhoeal disease in neonatal calves, lambs, and humans.

- ***Campylobacter*** is the biggest bacterial cause of human gastrointestinal disease in the UK and an important foodborne pathogen.

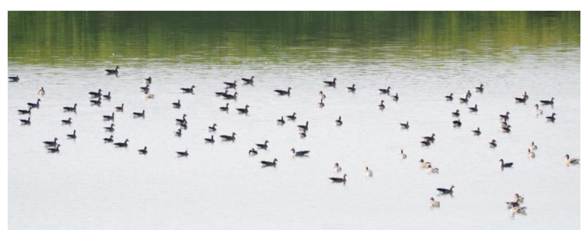
- **Antimicrobial resistance** (AMR) is a critical global health issue and it is vital that we better understand transmission of resistant bacteria within farmed and natural ecosystems.

Results reveal carriage of *Cryptosporidium* and *Campylobacter* by geese. DNA sequencing will be used to compare pathogen types obtained from geese, cattle and calves and look for evidence of transmission. Methods to extract bacterial DNA have been optimized for AMR gene profiling.

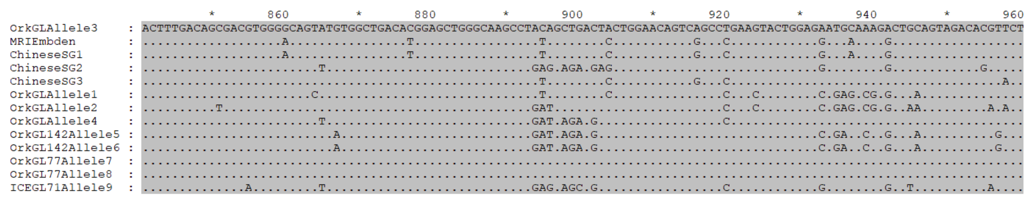
Wildlife genotyping

- Faeces provide a **non-invasive** source of DNA as samples can be collected from the ground.
- We have developed genotyping methods using goose faecal samples targeting mitochondrial & MHC diversity.
- This may enable different goose species / populations / family groups to be identified and potentially enable discrimination of migratory from resident geese (analysis is on-going).

Greylag geese in Orkney



Greylag geese in Iceland



MHC class II Diversity in Wild Orcadian and Icelandic Greylag Geese compared with the domesticated Embden and Chinese Swan Goose

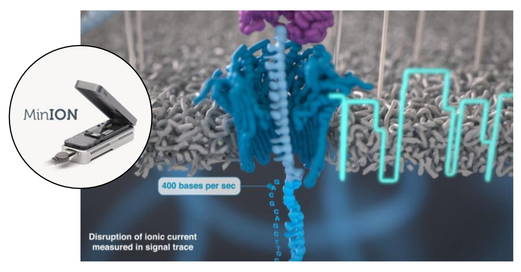
Results will be compared with microbial data to investigate correlations of pathogen carriage with specific goose cohorts.

Ecosystem sampling

- Ecosystem sampling enables transmission routes and reservoirs, as well as persistence of viable pathogens in the environment to be identified and investigated.
- We are investigating water, soil and sediment samples from farmed and wild ecosystems in Orkney and Iceland.
- For water samples, in-field filtration methods were developed to support bacteria culture and DNA analysis from remote sites.

New technologies

- We are trialling the use of a **cutting-edge sequencing technology** (Nanopore sequencing) for disease surveillance in wildlife and the environment
- Nanopore sequencing enables a global approach to pathogen identification and detection of AMR genes.
- Long reads of sequenced DNA can be used to identify which bacterial species carry which AMR genes.



epic Centre of Expertise on Animal Disease Outbreaks

Outcomes

- Results will be used to assess the **risk of goose faecal contamination** to livestock and public health and the development of strategies for disease control.
- This project will provide a **road map to support further studies** where engagement with a range of stakeholder groups is necessary and whose interests should be fairly represented.
- Methods will support additional **One Health studies** and **conservation efforts** related to wildlife diseases in changing environments.

Acknowledgements

- Orkney farmers
- The Orkney Goose Management Group
- Willie Stewart
- The local community

BioSS · Scottish Water · NatureScot NàdarAlba · RIF Field Station · Arctic Office · eastBIO · UKRI Biotechnology and Biological Sciences Research Council · INTER ≈ ACT · United Kingdom – Iceland Arctic Science Partnership Scheme

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An updated landslide susceptibility model for Scotland

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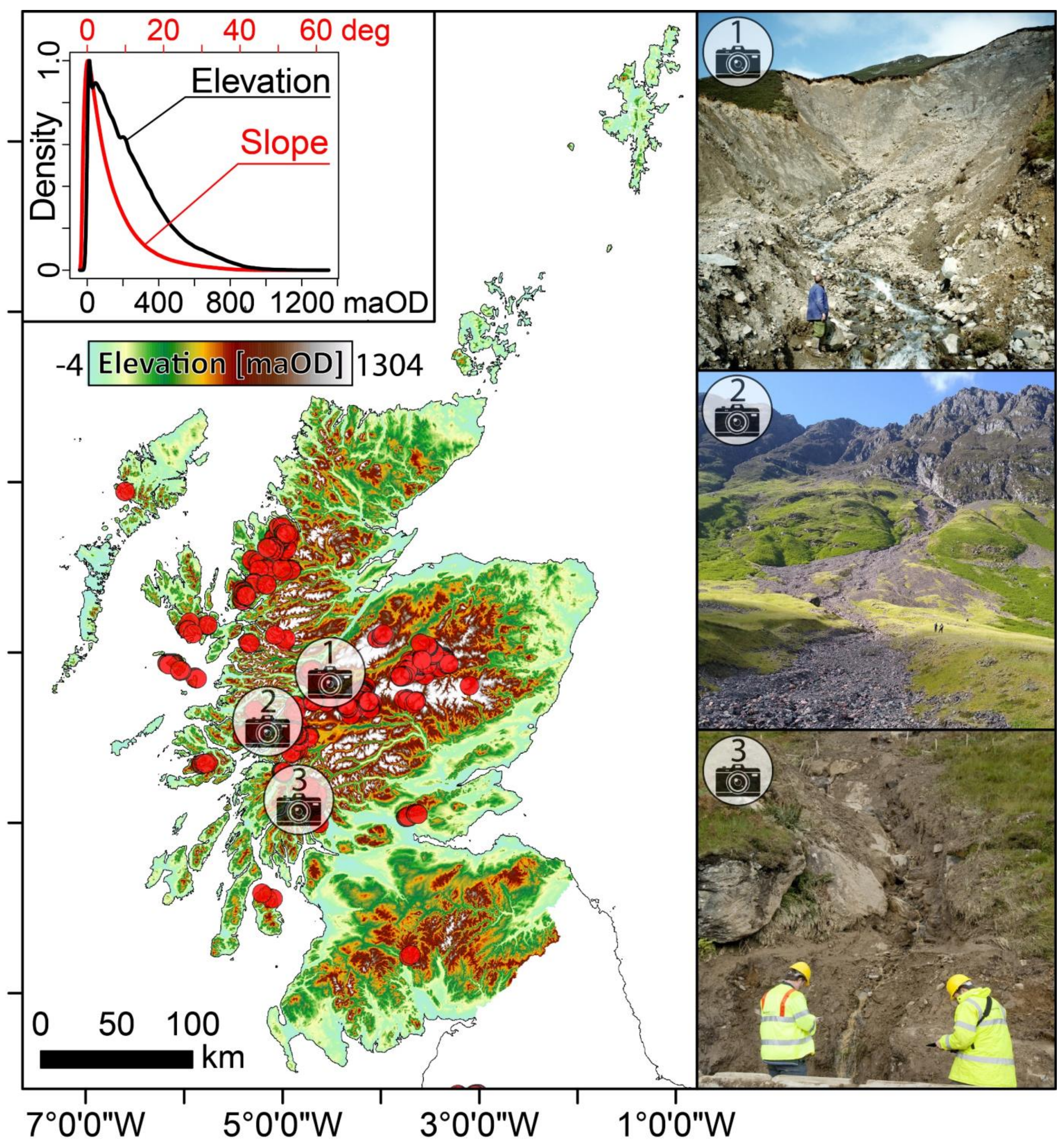
[2]British Geological Survey, Nicker Hill, Keyworth, NG12 5GG, United Kingdom.

[3]Department of Applied Earth Sciences, ITC, University of Twente, NL.

Introduction & Data

The GeoSure database of national landslides was sparsely populated at the time of its creation around 20 years ago, and therefore data-driven methods for landslide susceptibility were not possible. In this work, we look at landslide locations across Scotland, specifically debris flows (DFs), and aim to update the landslide susceptibility map that the British Geological Survey (BGS) has been using. To do this, we propose a Bernoulli likelihood model for the probability of landslide occurrence and a log-Gaussian Cox process (LGCP) model for the rate of landslide occurrences. We can then compare these data-driven susceptibility



maps with the previous heuristic map of GeoSure. In terms of data, we have a selection of geographical and geological covariates defined at the slope unit (SU) level. The SU is defined to preserve geo-morphological conditions that might induce landslides. The covariates underwent a forward selection procedure and information criteria were used to determine whether the covariate should be included in the model in a linear/non-linear way, or at all. In addition to this, we have the DF point locations, and from this determine the count per SU in order to use the grid-approximation method for our LGCP likelihood.

Modelling approach

For landslide susceptibility we model the probability of observing at least one DF in a slope unit by using a Bernoulli distribution. For the rate of landslide susceptibility, we model the DF rate of occurrence per SU by using a Poisson distribution with a random intensity function which approximates the LGCP likelihood.

In both cases, we assume that the observations are conditionally independent given a latent Gaussian field. This latent field can be represented as the sum of our model components:

$$\eta(\boldsymbol{s}) = \alpha + \sum_{m=1}^{M} \beta_m w_m(\boldsymbol{s}) + \sum_{k=1}^{K} f_k\big(z_k(\boldsymbol{s})\big) + u(\boldsymbol{s})$$

These type of models (flexible and hierarchical) are best understood within a Bayesian framework and here we utilise the integrated nested Laplace approximation (INLA) to infer our posterior distributions of interest. Additionally, we use the stochastic partial differential equation approach (SPDE) to model our spatial random effect.

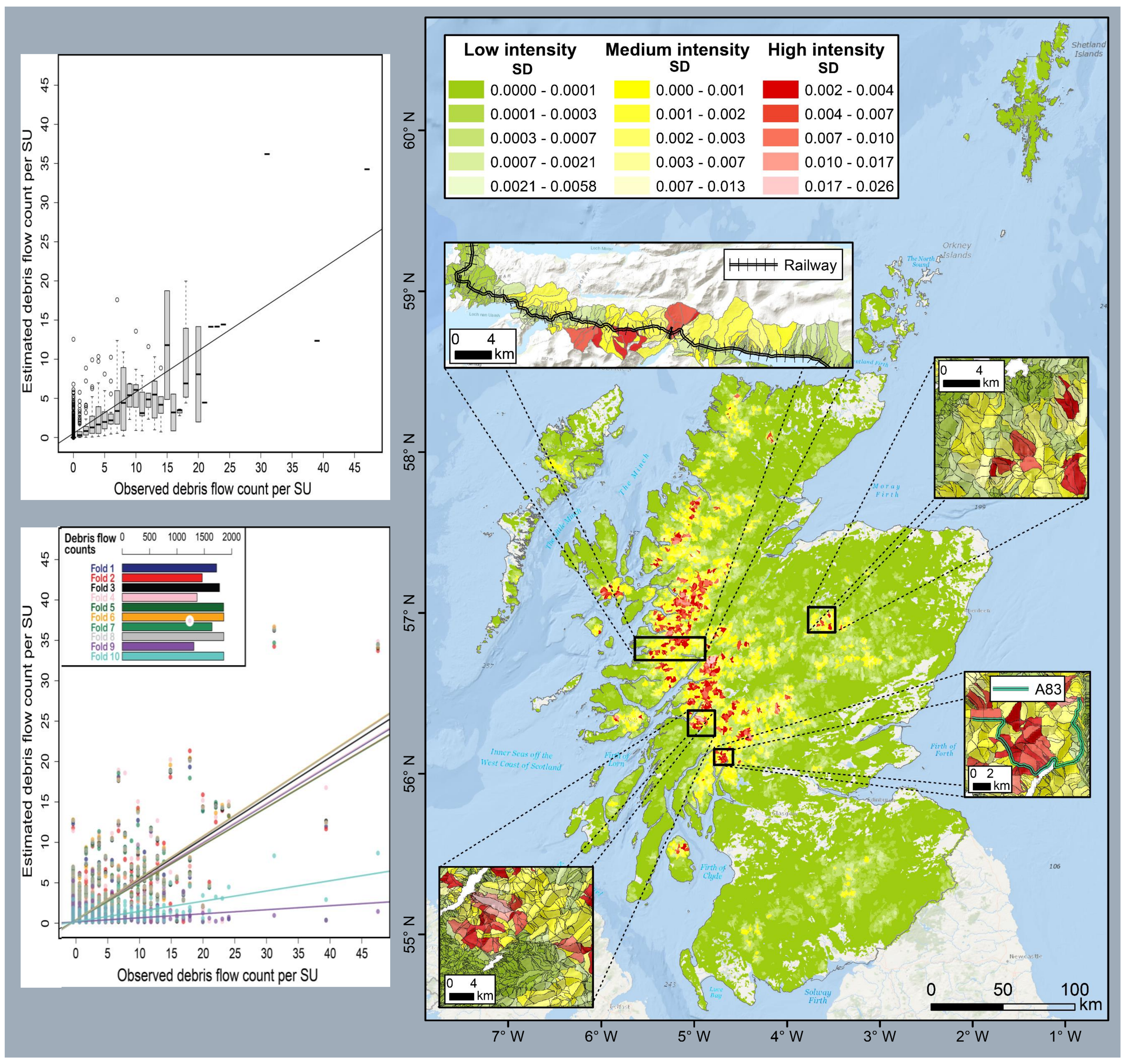
Bernoulli model equation:

$$y(\boldsymbol{s}) \mid \eta_{Bern}(\boldsymbol{s}) \equiv Bern(p(\boldsymbol{s})), \text{ where } p(\boldsymbol{s}) = Pr\{O_{DF}(\boldsymbol{s}) = 1\}$$
$$p(\boldsymbol{s}) = exp\{\eta_{Bern}(\boldsymbol{s})\} \,/\, (1 + exp\{\eta_{Bern}(\boldsymbol{s})\})$$

LGCP model equation:

$$y_{LGCP}(\boldsymbol{s}) | \eta_{LGCP}(\boldsymbol{s}) \sim \text{Pois}(\lambda(\boldsymbol{s})) \equiv \text{Pois}(|\boldsymbol{s}| \exp(\eta_{LGCP}(\boldsymbol{s})))$$

Results



Conclusions

The DF susceptibility and DF intensity maps both captured the areas in which to focus in terms of a higher DF risk. The LGCP model intensity map, however, pinpoints these areas with a higher degree of accuracy due to the nature of the point process modelling approach. Both models do well in terms of model performance, although validation measures for point-process models are generally complex and more along the lines of a residual analysis to compare variations of the model.

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GREENGrass – exploring regenerative agriculture for grazing sheep

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See our blog...

The background:

Livestock, and livestock health and welfare, should be considered in the conversation around sustainable food production.

Roundworm infections are a major constraint on livestock production, which are affected by climate and farm management and result in reduced efficiency and increased emissions

Introducing regenerative grazing practices, such as rotational grazing and integrating legume crops, has been estimated to result in up to a 38% reduction in emissions intensity from livestock[1].

There is scant scientific evidence for impacts of rotational grazing or biodiverse sward on animal health, welfare and production in the UK

Aim: to evaluate the effects of regenerative livestock grazing practices on animal health, productivity, parasite abundance and wormer use

The research:

Field trial in progress to compare different regenerative grazing practices, in a 2 x 2 design (Figure 1), in a paired trial with JHI, Glensaugh:

- rotational grazing versus set stocking
- traditional rye grass/clover versus improved biodiverse (see Figure 2)
- 10 lambs per paddock, 4 treatments, 3 replicates = 120 lambs in total

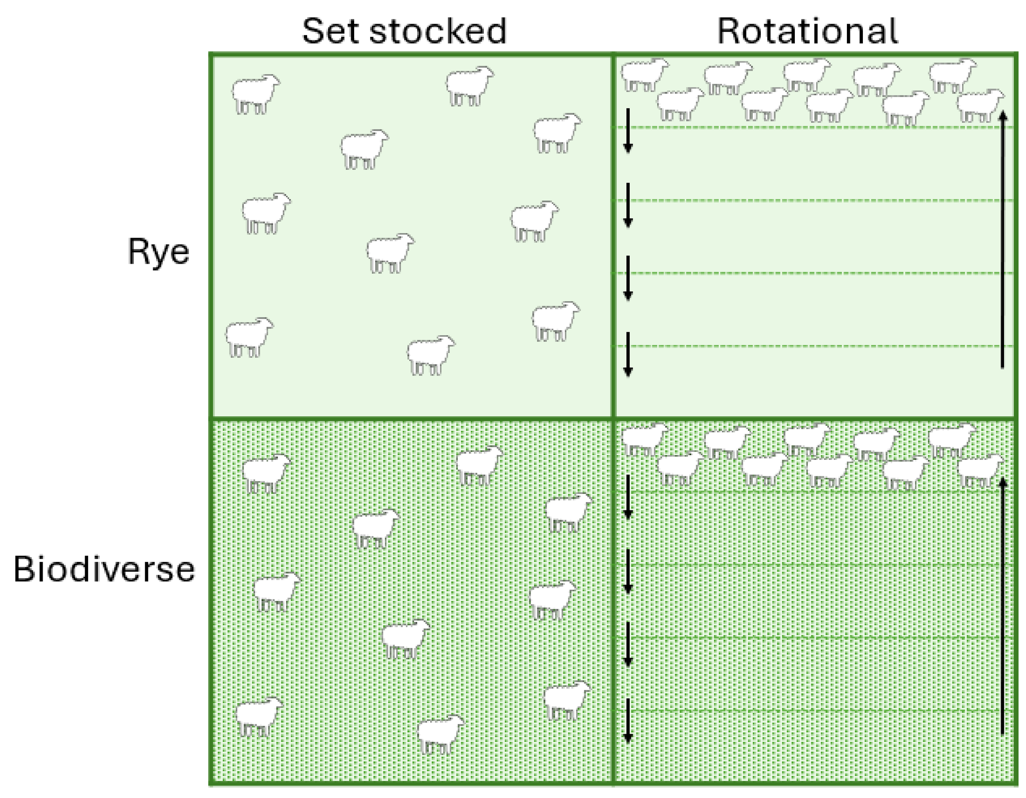
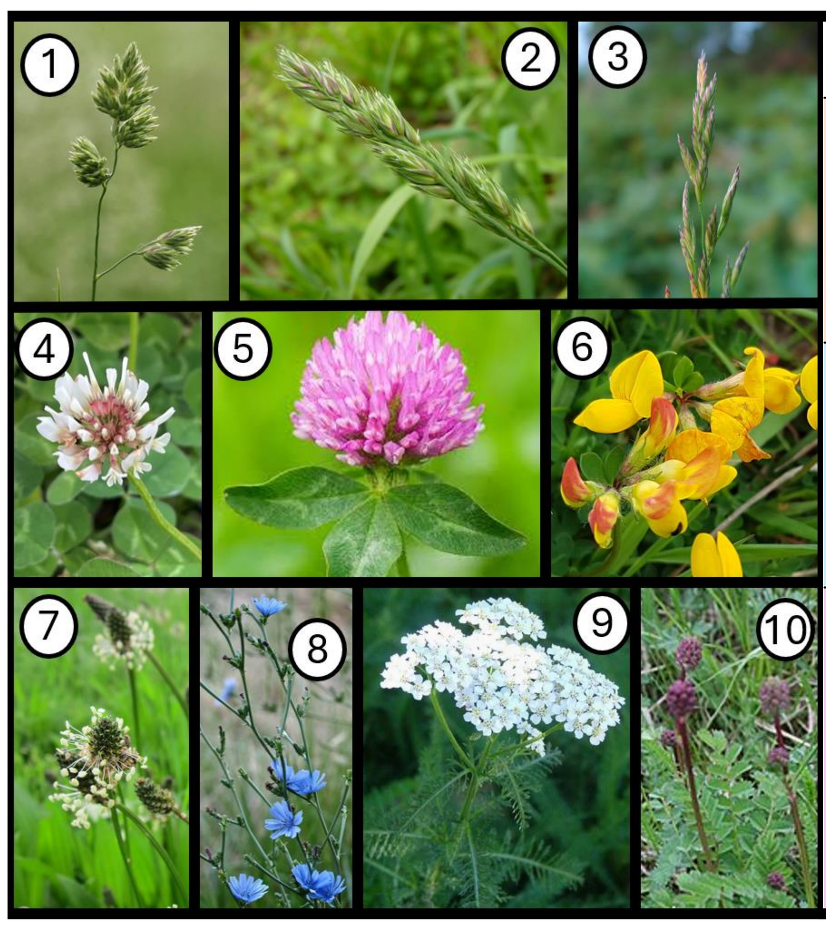


Figure 1. The 4 treatment groups in a 2 x 2 design



Key	Plant name	Species	Type
1	Cocksfoot	*Dactylis glomerata*	Grass
2	Meadow fescue	*Festuca pratensis*	Grass
3	Tall fescue	*Schedonorus arundinaceus*	Grass
4	White clover	*Trifolium repens*	Legume
5	Red clover	*Trifolium pratense*	Legume
6	Birds-foot trefoil	*Lotus corniculatus*	Legume
7	Ribwort plantain	*Plantago lanceolata*	Herb
8	Chicory	*Cichorium intybus*	Herb
9	Yarrow	*Achillea millefolium*	Herb
10	Salad burnet	*Sanguisorba minor*	Herb

Figure 2. Biodiverse species composition, direct drilled into existing rye grass/clover pasture

Sample collection and analysis:

From each lamb every 2 weeks from May to October a range of samples was collected to measure numerous variables (Figure 3)

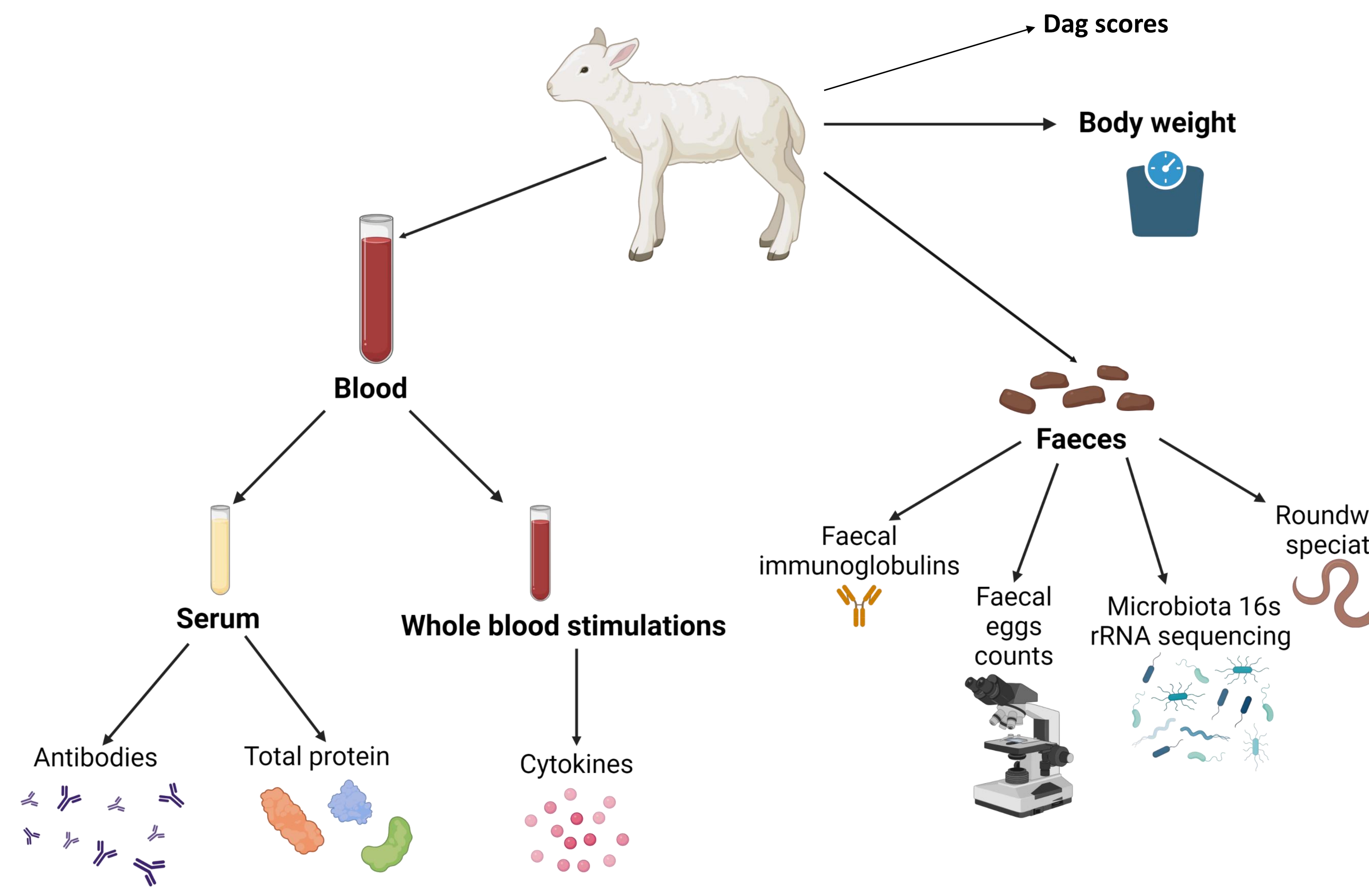


Figure 3. The sampling undertaken and analysis

The results:

There is no difference in weight between treatment groups, but a potential difference in antibody response towards the end of the trial (Figure 4 A and B)

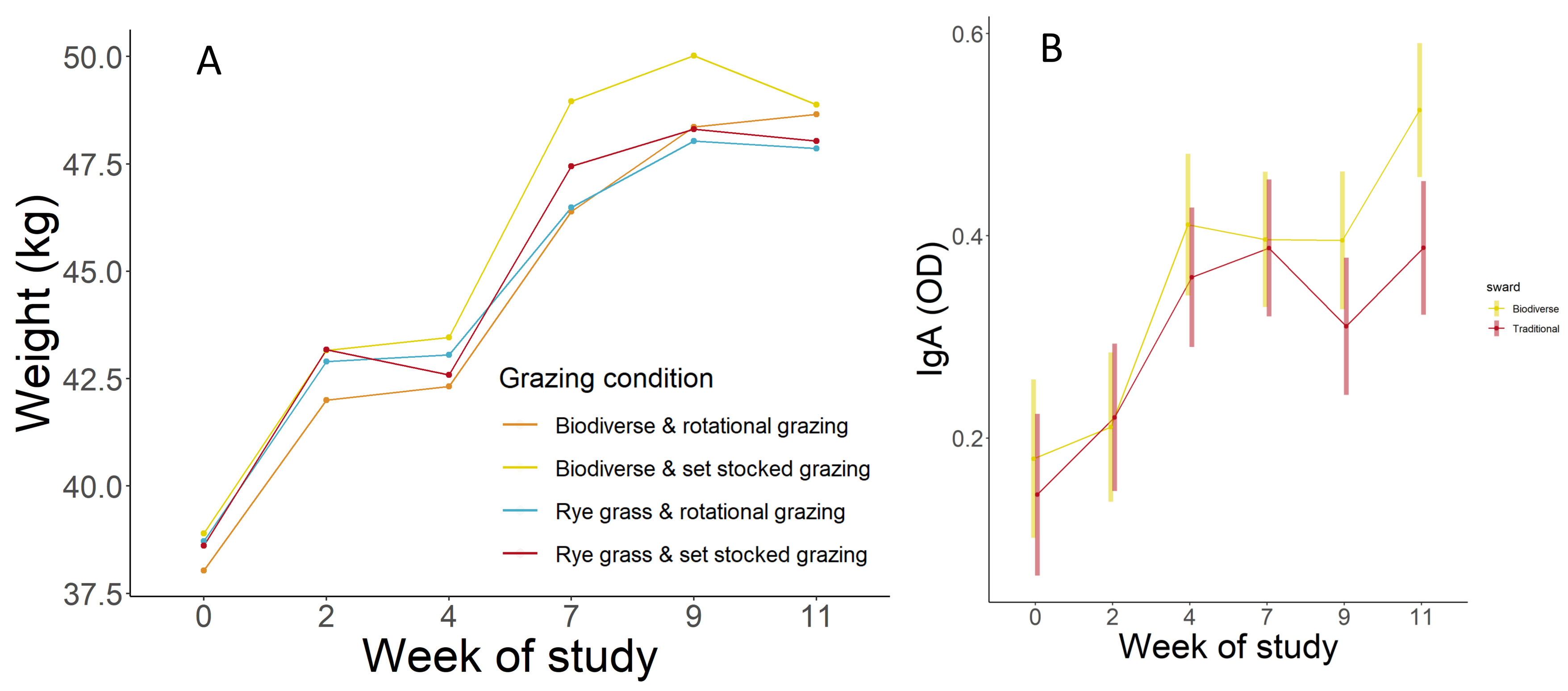


Figure 4. A. The weight of the lambs in each treatment group and B. IgA (a measure of immune response) throughout the study

Moredun Research Institute · Scottish Government Riaghaltas na h-Alba gov.scot · RESAS Rural & Environmental Science and Analytical Services · The James Hutton Institute · SEFARI

This project received funding from the Scottish Government Strategic Research Programme 2021-2027, MRI-B2-1

1. World Wildlife Fund '*Reaching Net Zero in Scotland*' Report 2019)

Resilience to Fluvial Flooding: Knowns and Unknowns

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What do we know and what we don't know about fluvial flood risk, resilience and management? Here we critique both scientific understanding through literature review and stakeholder knowledge through engagement to give us a clear picture of the current state of the art and provide recommendations for Scotland's Flood Resilience Strategy.

Background

Policy Fellowship critiqued our current state of knowledge with respect to fluvial flood management to inform Scotland's Flood Resilience Strategy.

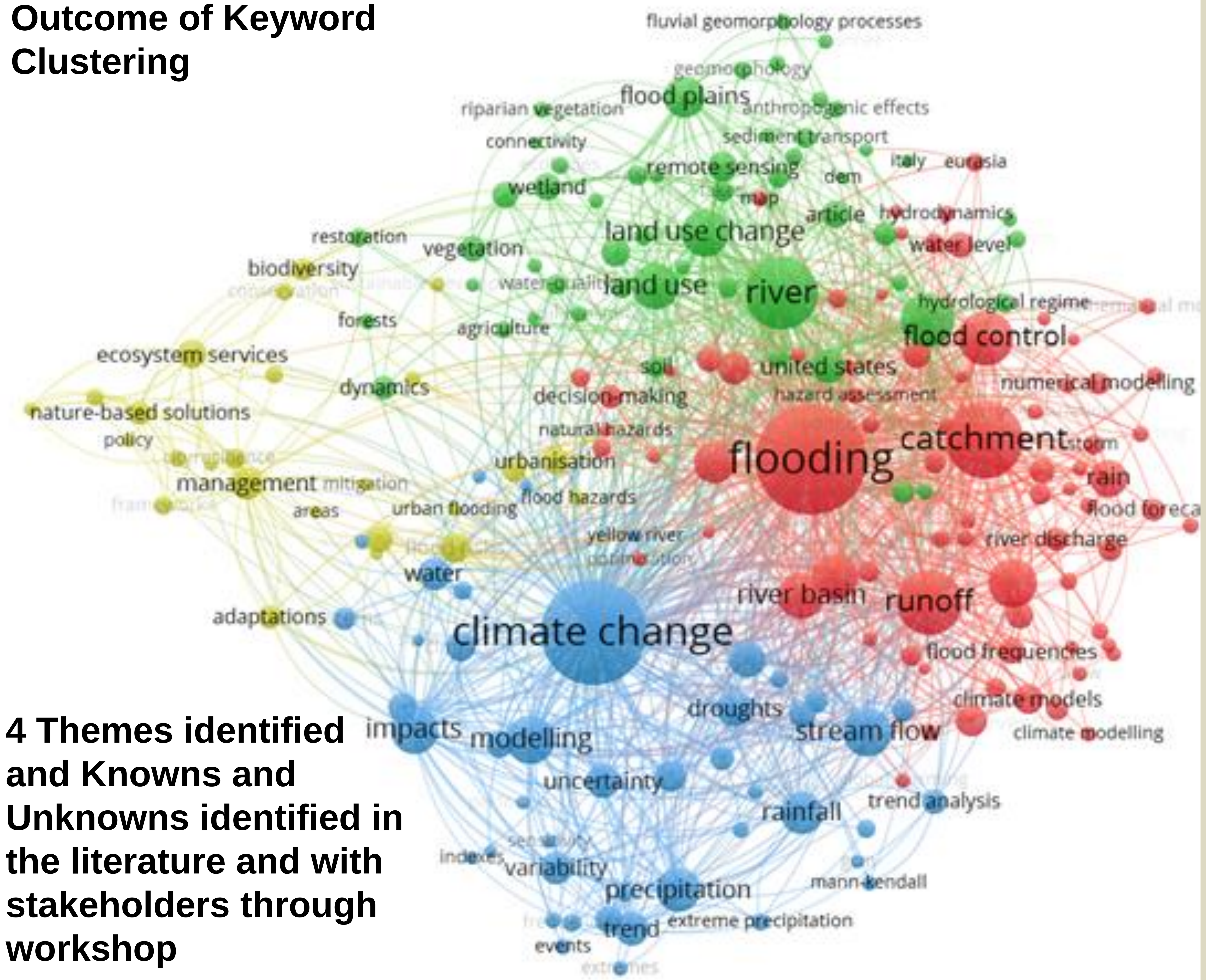
Research

We have used the epistemological construct of "Known Knowns, Known Unknowns and Unknown Unknowns" to assess scientific knowledge on fluvial flooding through a literature review and stakeholder workshop.

We used a wide range of search terms and combinations thereof relating to fluvial flood risk generation, management, and resilience using the Scopus and Web of Science platforms.

We utilised the power of AI to synthesise a large volume of information in an efficient manner to highlight emerging themes. This was done using VOSviewer, which analyses and visualises bibliographic networks. A co-occurrence analysis of the top 1000 keywords was conducted.

Outcome of Keyword Clustering



4 Themes identified and Knowns and Unknowns identified in the literature and with stakeholders through workshop

Climate Change

Knowns	Unknowns
Increased rainfall in winter months expected to increase the frequency and severity of fluvial flooding.	Absolute estimates of climate change impacts on rainfall and flooding are uncertain.
Changes not spatially uniform; it is estimated that catchments in the N and W of Scotland impacted most.	Complex regional climate models and projections are probabilistic and provide estimates of uncertainty.
	Compounded by uncertainty of other forcing factors e.g. land use change

Flood Generation

Knowns	Unknowns
Lag times between peak flows from different tributaries control the the magnitude and shape of the downstream hydrograph.	Can NFM achieve time lag delays needed to desynchronise tributary peaks and reduce downstream floods in larger catchments?
Desynchronising flood peaks from different tributaries reduces the magnitude of the flow downstream.	Hydrograph convolution from upstream catchment vary in space and time and are context-specific.
Conversion of rainfall to runoff is a non-linear process and is dependent upon the catchment characteristics.	Complex non-linear and scale dependent processes.

Natural Flood Management

Knowns	Unknowns
Proven effective for high-frequency, low return period, small storms.	Not proven effective for large storms or in large catchments.
Increase the "lag time" between rainfall and peak river levels.	Lack of data and relatively small-scale implementation to date.
Combined with hard engineering approaches to increase effectiveness	More data needed range of events, locations, and contexts.
Brings additional benefits e.g. biodiversity, carbon storage	

Working with Stakeholders

Knowns	Unknowns
Funding is only one of many issues that can affect NFM implementation.	Uncertainty in realm of politics and decision-making processes.
Calls for increased and meaningful public participation in management.	Making management equitable, providing benefits across society
Memory is an important factor in community perceptions of flood risk.	Finding right balance of NFM, grey infrastructure, do-nothing, and retreat is a difficult task that requires input and negotiation from affected people

Recommendations

1. Mainstream and upscale Natural Flood Management (NFM) and/or Nature-based Solutions (NbS) implementation, supported by monitoring and maintenance. Ensure NFM is assessed holistically for use alongside hard engineered solutions.
2. Contextualize flood management decisions to take into account hydrological complexity, non-linearity, and the unique geography of each catchment. One solution does not fit all.
3. Shift to adaptive planning, to account for future uncertainty associated with climate change, including in terms of mindset of planners, economic appraisal, and funding mechanisms.
4. Encourage community co-creation of flood management for place-based, socially accepted policies, relating to standard of protection, risk perception, and balance of options.
5. Address the many gaps in our knowledge, highlighted by scientific confidence assessments and Unknown Unknowns, which need future research.

Understanding Potato Cyst Nematode decline rates to preserve Scottish potato-growing land

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The James Hutton Institute

Introduction

Potato cyst nematodes (PCN) are currently the greatest pathogenic threat to the Scottish potato sector.

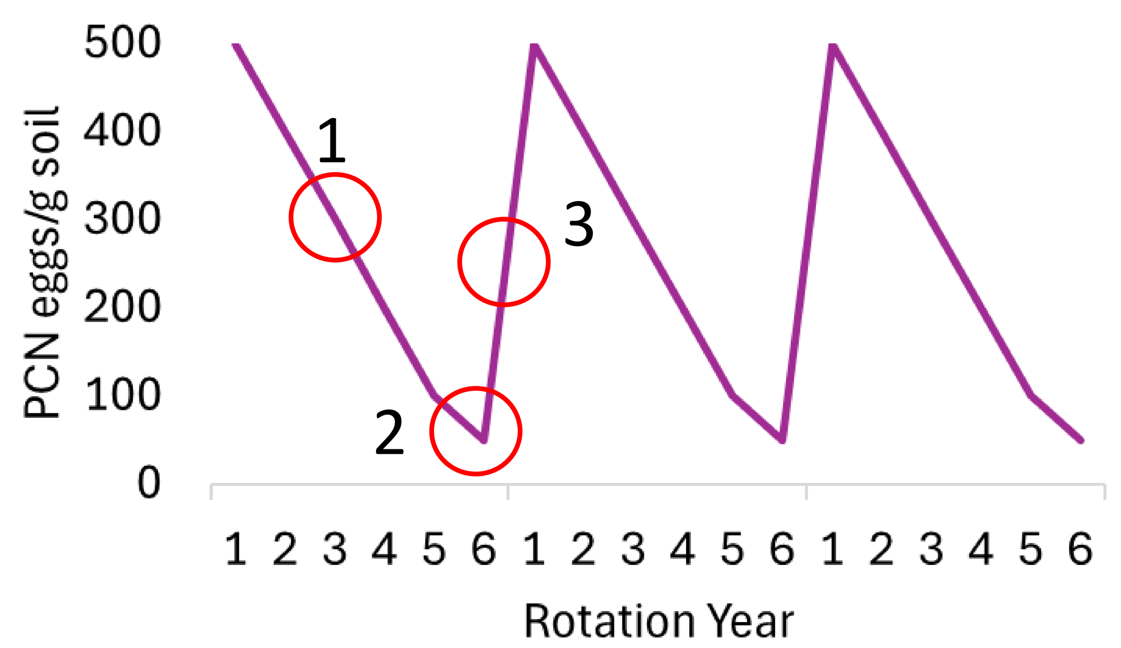
Predictions suggest that PCN could collapse the Scottish seed industry by 2050.

Knowledge of how PCN populations decline in the absence of a host is vital to support agronomic practices and management strategies.

However, little is known about population decline under Scottish conditions and how this might be affected by climate change.

This project supports novel zero-waste management techniques and informs large grower-directed initiatives such as the Scottish Plant Health Centre's 'PCN Action Scotland'

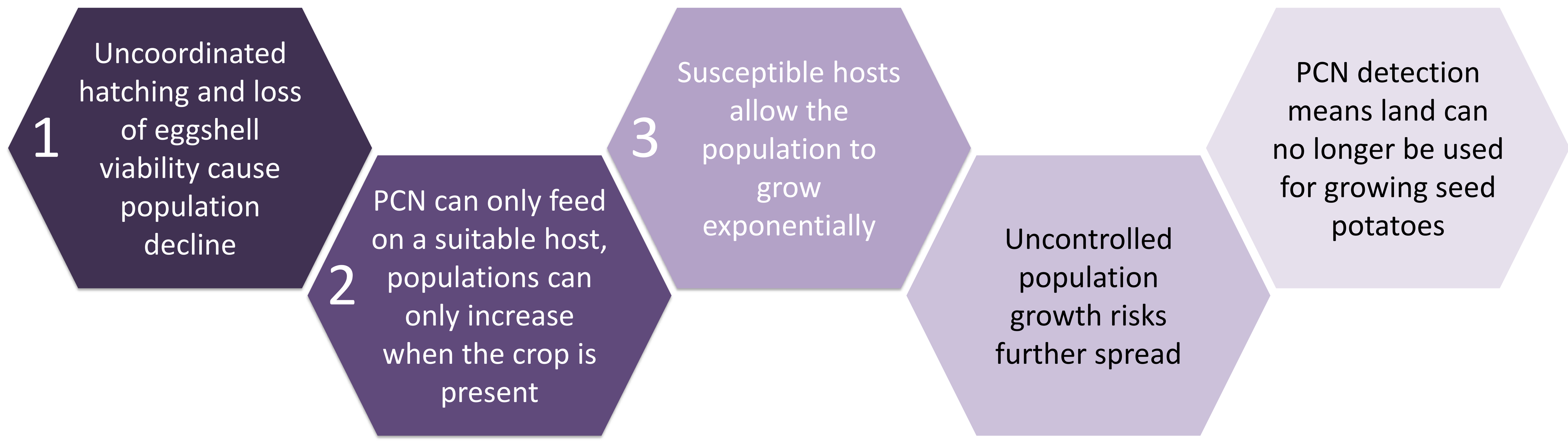
What is a decline rate?



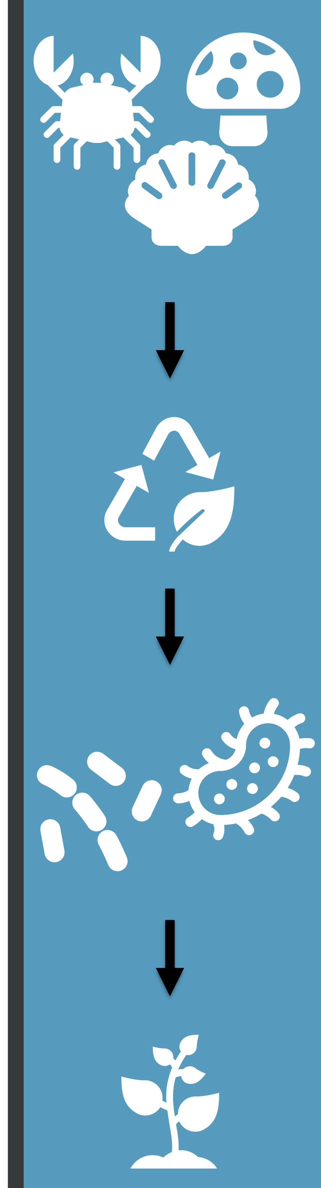
Natural decline of PCN populations varies with factors including **temperature, soil type, and moisture.**

Understanding this is crucial for modelling PCN spread and establishment.

However, **there is limited data on PCN decline under Scottish conditions** and the potential effects of **climate change**.



Soil amendments and sustainable soils



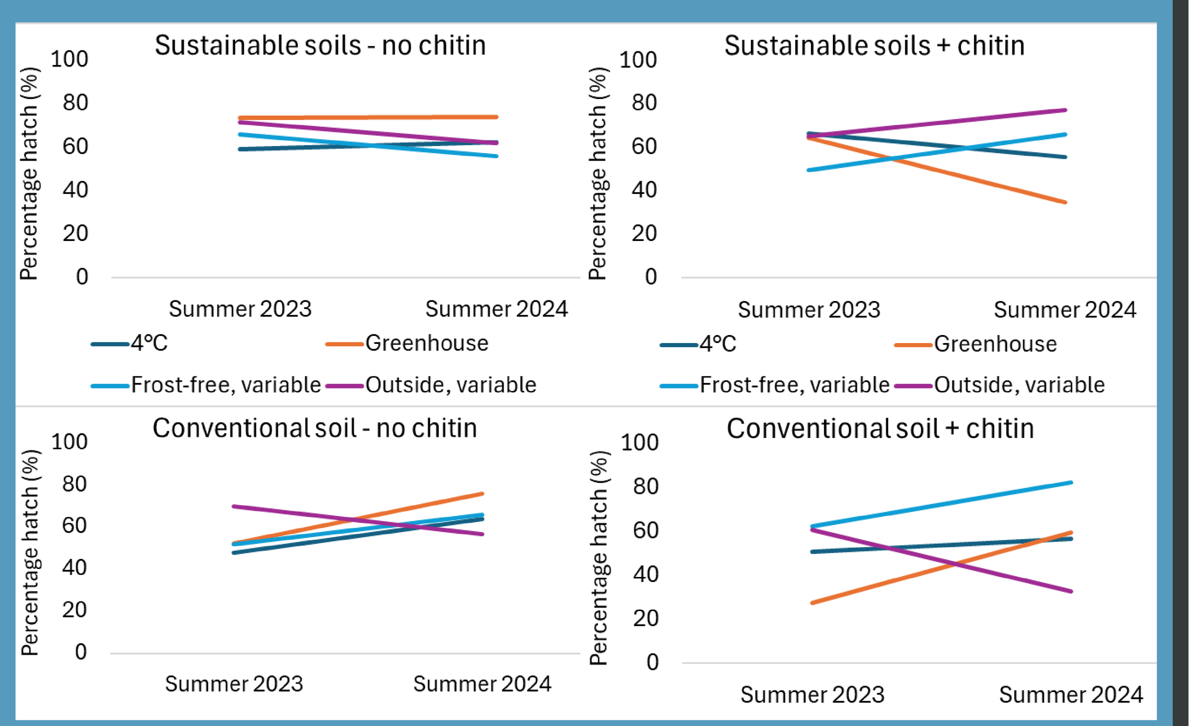
Shellfish and mushroom waste can be composted into a **chitin-rich soil amendment** that returns nutrients and introduces chitin degrading microorganisms to the soil.

These organisms consequently target chitin in PCN eggshells, **disrupting hatching and increasing natural PCN decline**.

Additionally, plants can recognise chitin, priming their defence against pathogens.

Sustainably managed soils have been developed **at Balruddery Farm (Hutton)** using integrated crop systems. This includes practices such as reduced tillage, use of organic matter amendments, reduced fertiliser use and biodiversity management.

The Research



Experiments were carried out under controlled and varying environmental conditions to assess the effect of chitin amendment and sustainably managed soils on hatching of PCN. Microcosms are being sampled every 6 months for PCN viability. The first year of this project has demonstrated that combinations of both soil management strategy and chitin-rich amendments can increase PCN decline.

Conclusions

- Under constant temperature conditions chitin-rich soil amendments increase PCN population decline in sustainable soils.
- The benefit of chitin-rich soil amendments is currently seen in conventionally managed soils.
- The data does not currently suggest that warmer soils resulting from climate change will have a noticeable impact on PCN decline.

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The Development of a Human Behaviour Change (HBC) Intervention to Increase the Adoption of Body Condition Scoring Cattle by Hand: *What are the Barriers & Drivers of Change*?

Dr. Lesley Jessiman[1], Dr. Kenny Rutherford[1] & Professor Simon Turner[1]

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Introduction

Excessive leanness or obesity in pregnant animals can have undesirable health and welfare outcomes both for the dam and for developing fetal progeny. In cattle, extreme leanness contributes to calving difficulty, poor calf development and subsequent failure of the mother to conceive again.[1,2] Obesity also represents an inefficient use of feed resources with financial costs to the farm business and an associated environmental cost. Adjusting food quantity and quality to maintain body fat within an acceptable range is therefore expected to deliver multiple benefits. Despite this, a recent study of commercial beef farms in the UK found that 20% of pregnant cows were too lean prior to spring calving.[3] The recommended approach for monitoring fat deposits in a practical context is body condition scoring (BCS), which requires use of the hand to provide a subjective judgement of subcutaneous fat depth at key points on the body. Animals are then assigned a value on a categorical scale. BCS can be conducted quickly when performed alongside other routine animal handling tasks. Despite the apparent ease of BCS and the benefits of maintaining body condition within an acceptable range, only 4% of UK beef farmers use the recommended approach of using their hands.[4] Our own research also reveals that most farmers tend to judge body condition from a distance by eye without using the hands. In the UK, the recommended hands-on approach to body condition scoring and the associated scoring scale have been advocated for over 50 years. The low uptake contrasted against the expected benefits of optimum body condition management suggest an ingrained reluctance to adopt the approach. This study aims to understand the barriers responsible for this poor uptake.

The Behaviour Change Wheel

There have been several studies that have examined the influences on farmers'/stockpersons' behaviours and cognitions in relation to animal health & welfare[5]. However, a significant proportion of these studies refer to individualistic theories to explain behaviour(s) thus often falling short of accounting for the complex interplay between the individual and the social, economic, historical, and cultural factors. Given what we know about the complex nature of farming and animal welfare-related issues, it is important that we fully understand the influences on a desired behaviour such as BCS by hand. One theoretical model that considers the complex and synergistic nature of human behaviour is the Behaviour Change Wheel (BCW).[6] Drawing from the BCW we therefore aim to identify the likely barriers and drivers of BCS by hand to develop a potential intervention to increase the adoption of BCS in the future.

Methods

Participants & Ethical Approval

- The data was collected from six focus groups. All focus groups took place during a knowledge exchange event or farming/farmers meeting. Open-ended survey data was also collected from 25 farmers/stockpersons.
- Ethical approval was granted from SRUC Social Science Ethics Committee, Protocol # 73026312.

Materials & Procedure

- A semi-structured interview schedule was used to facilitate the discussions in the focus groups.
- The focus groups were moderated by one of the animal welfare researchers (ST). The focus groups were recorded using a high-resolution WAVE/MP3 recorder. Each focus group lasted between 25 & 40 minutes. The focus groups were then transcribed and validated. The data then went through a systematic coding & analysis process to identify and develop a potential human behaviour change intervention; guided by the steps outlined in the BCW and outlined in the following section.

HBC Mapping & Intervention Design: Data Analysis

Stage 1. Coding of the Farmers' Shared Beliefs using Content Analysis

- The transcripts were content analysed by one of the researchers (LJ) & later reviewed by another researcher (ST). The first stage in our content analysis approach was guided by our research questions: 1. What are the barriers and drivers of body condition scoring by hand? and 2. What are farmer's perceptions and beliefs around the conditioning of their cows?

Stage 2. Mapping Farmers' Beliefs onto the TDF Domains & Constructs

- In stage 2, three psychologists acted as reviewers & read through the list of barriers and drivers identified. The reviewers then mapped the farmers' shared beliefs or themes on to the domains and constructs identified in the Theoretical Domains Framework (TDF)[7] of the BCW.[6]

Stage 3. Linking the TDF domains and COM-B components on to the BCW Intervention Functions.

- In stage 3, one of the researchers (LJ) mapped the agreed TDF domains from stage 2 on to their respective COM-B components to provide a "behavioural diagnosis" i.e., in terms of what needs to change to achieve our desired/target behaviour (i.e. adoption of BCS by hand). Following the relevant BCW steps, we then linked the behavioural diagnosis with the relevant intervention functions.

Stage 4. Linking BCW intervention functions to policy categories & applying APEASE criteria to both

- In stage 4 of our intervention design, we mapped the intervention functions on to their specific policy categories as guided by the BCW. Each of the policy categories have been identified as best supporting the delivery of the respective intervention functions. The BCW policy categories, which form the outer circle of the BCW (see Figure 1 below), represent the types of decisions that governments or organisations might make to fund, support, and enact an intervention. The APEASE criteria were then applied to the interventions and policy categories.

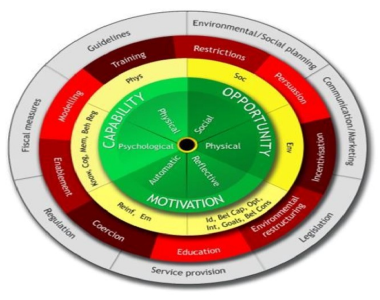

Figure 1. The Behaviour Change Wheel[6]
The wheel illustrates the COM-B model (green), TDF framework (yellow), Intervention functions (red) & Policy Categories (grey)

Stage 5. Linking the intervention functions and TDF domains to the Behaviour Change Techniques (BCTs)

- Using the BCW, the BCT Taxonomy online resource[8] and the BCTTv1 Smartphone App[8], potential BCTs for each of our TDF domains and intervention functions, which met the APEASE criteria in stage 3, were identified.

Image: Professor Simon Turner demonstrating BCS by hand

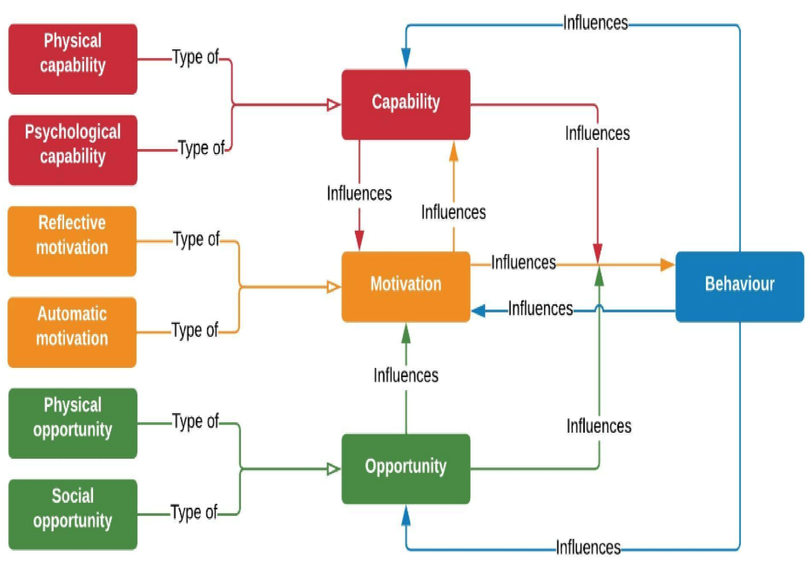

Figure 2. COM-B Model of Behaviour[10]
The figure illustrates the synergistic nature of behaviour e.g., if there is opportunity &/or capability but a lack of motivation or *vice versa*, the behaviour will not occur.

Results

HBC Mapping: Stage 2 analysis

- An overall moderate agreement between the reviewers in their mapping of beliefs to the TDF domains was found Fleiss's kappa=0.455 (95% CI, 0.305 to 0.605), p < 0.001.
- Individual Kappa revealed good agreement for ***Environmental Context and Resources***, K=0.717 (95% CI, 0.415 to 1.02) p <0.001, and ***Beliefs in Consequences***, K=0.692 (95% CI, 0.252 to 0.857) p <0.001.

The Behavioural Diagnosis

- The intervention functions that were found to be potentially feasible after applying the APEASE criteria were ***Education, Enablement, Training, Modelling & Persuasion***.
- The policy categories found to be potentially feasible after applying the APEASE criteria were ***Communication/Marketing, Guidelines, & Service Provision.***

APEASE

Acceptability
Practicability
Effectiveness
Affordability
Spillover effects
Equity

Conclusions

- Drawing on the BCTs that we identified from our intervention design stages 1-5, we were able to design a potential intervention, which we plan to implement & assess.
- The BCTS we will include in our intervention are : 1. Information about social & environmental consequences ; 2. Information about health (animal) consequences; 3. Feedback on behaviour or on outcome(s) of the behaviour; 4. Self-monitoring of behaviour or outcomes of behaviour & 5. demonstration of behaviour from a credible source.
- We will be running workshops that are directly informed by our intervention design e.g., BCS demonstrations from the animal welfare researchers & other farmers who know how to BCS by hand (our credible sources).
- We will create guidelines that are directly informed by our BCW diagnosis /intervention design.
- The phase of change of the farmer/stockperson – another important factor in any HBC design – will also be considered.

Acknowledgements

Special thanks go to the Scottish Government for funding this project as part of the SRUC A3-4 : Influencing Human Behaviour to Improve Animal Welfare program. Another special thank you to all the farmers and stockpersons who participated in our study.

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Agriculture Health Equity Nexus in the context of climate change

A rapid evidence review

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2.World Health Organisation (WHO)

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Introduction

The link between poverty and health inequalities is well established as those living in poverty are more likely to experience both inequitable health service provision and adverse social and environmental determinants of health. Given the role of agriculture as a primary livelihood for the world's extremely poor (World Bank 2020), this research takes a holistic approach to agriculture and health (including health equity) equity to examine the linkages and to understand the main interfaces between health and agricultural policy that integrated rural policy could address.

This poster summarises the preliminary results from research commissioned by the World Health Organisation to SRUC exploring the agriculture and health equity nexus. It builds upon previous work by Swift Koller (forthcoming) which identified key components of the Nexus using thematic analysis. The results of this work will be reported in a World Health Organisation report in 2025.

Methods

This project used multiple methods including:

i) A rapid evidence review of literature, ii) discussions/workshop with experts and iii) case studies

The rapid evidence review looked at literature in the SCOPUS database that related to the domains as identified in the Agriculture- Health Nexus (Swift Koller and Chater, forthcoming).

Following this discussions with experts were used to identify gaps. The case studies cover school feeding programmes, social farming, farmer field schools, mental health of agricultural workers and collaboration for tuberculosis. Case studies were selected to highlight the success of a variety of initiatives across different domains of the Agriculture – Health Nexus in different contexts.

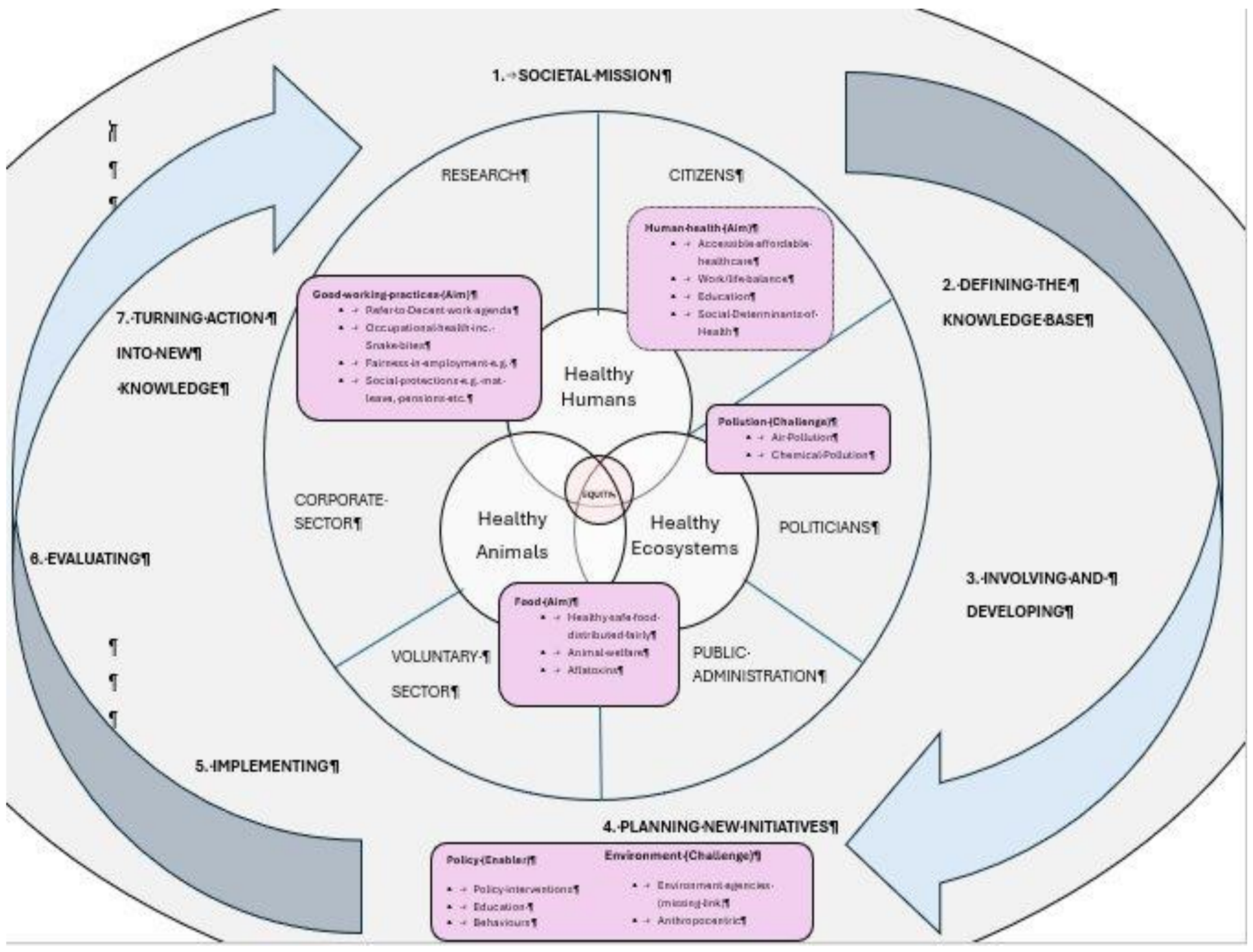
Recommendations

The findings from the various activities were synthesised and explored to produce the rapid evidence review. These results were also to update the Agriculture-Health Nexus model to include the environmental domain aligning it more to a One Health perspective (see Figure 1).

Key recommendations from the report include:

1.Policy coherence
2.Service delivery platforms/mechanisms
3.Information systems and data
4.Governance for health equity
5.Empowering communities through participatory research for Place-Based Solutions
6.Integrating local knowledge and initiatives with Top-Down approaches to build community resilience
7.Creating inclusive and adaptable strategies for cross-sector collaboration
8.Expanding GIS technology to enhance human capital and health outcomes
9.Strengthening antimicrobial stewardship and surveillance to combat AMR
10.Ensuring Safe and Nutritious Food is Fairly Distributed

Figure 1 – Adapted model depicting necessary steps for achieving sustainable and equitable outcomes through One Health model:



Future work

This work will be finalised over the next few months and will be published in a WHO report in 2025. This work further highlights the linkages between human, animal and environmental health and the transdisciplinary approaches required to work across these areas.

Acknowledgement

This project was commissioned by the World Health Organisation to SRUC and funded by the Government of Canada grant "Strengthening Local and National Primary Health Care and Health Systems for Recovery and Resilience of Countries in Context of COVID-19".

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Legume-based intercropping: A pathway to reduced N_2O emissions from agriculture?

Luke Harrold, Kairsty Topp, Christine Watson & Robin Walker

Introduction

- Intercropping of legumes with cereal crops can play a crucial role in the path towards sustainable agriculture and achieving net-zero.
- Literature and IPCC report suggests a reduction in N_2O emissions in legume intercropped systems. However, reductions have been shown to be dependent on the variety of pea used.
- We aim to explore if legume-based intercropping systems (pea/barley) can support sustainable farming by balancing environmental (N_2O emission, soil health) and economic (yield) goals.

Methods

Treatments

Barley and pea were planted in isolation (Sole crop) and together (Intercrop) using three fertilizer rates (Table 1)

Plots organized in a randomized block design, replicated four times.

Table 1 – Crop treatment including fertilizer addition

Treatment	Fertiliser
Sole crop Barley (Laureate)	Full N 120 kg/ha
Sole crop Pea (Prophet)	No N
Intercrop Barley/Pea	No N
Intercrop Barley/Pea	Half N 60 kg/ha
Sole crop Barley	No N

Sampling

Gas sampled from chambers (Figure 1) on days 1,2,4,8 and 10 then twice a week for four weeks followed by once per month until experiment end.

N_2O concentration measured via gas chromatograph.

Periodically soil samples were taken to determine soil nitrogen in the form of NH_4^+ and NO_3^-.

Soil moisture and temperature were also measured continuously on an hourly basis using soil probes and a data logger.

Figure 1 – Gas sampling from static chamber. Two static chambers per subplot. Photo by Robin Walker.

Figure 2 – Plots with stacked chambers. A few weeks before harvest

Also measured

Bulk density
Infiltration
Soil carbon
Soil structure (VESS)
Earthworm count

Results

N_2O flux closely linked to soil water content, peaks corresponding to higher soil moisture (Figure 3).

Significant differences in cumulative N_2O emissions are seen within 21 days (Figure 4).

N addition to barley doubled N_2O emissions over 21 days compared to no-N barley (Figure 4).

No difference between sole crop pea and sole crop barley with no N (Figure 4)

Intercrop with half standard N rate had the same N_2O emissions as full-rate barley treatment (Figure 4).

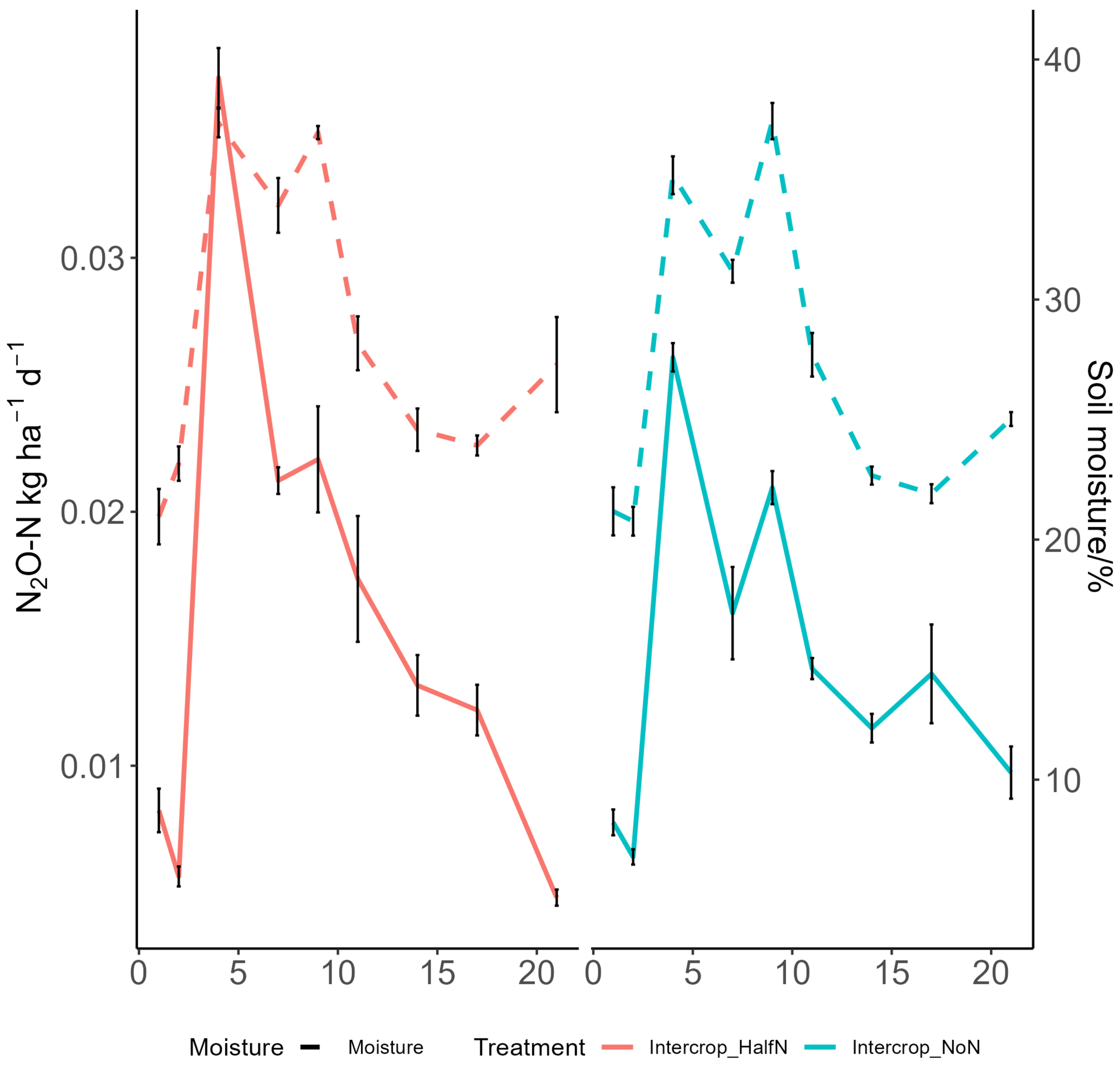

Figure 3 – N_2O flux and soil moisture for the first 21 days of Intercrop-Half N (left) and Intercrop No N (right). Solid lines show the flux of N_2O over time with the left-hand y-axis. Dashed lines show the soil moisture content (%) overtime with the right-hand y-axis. Standard error is shown.

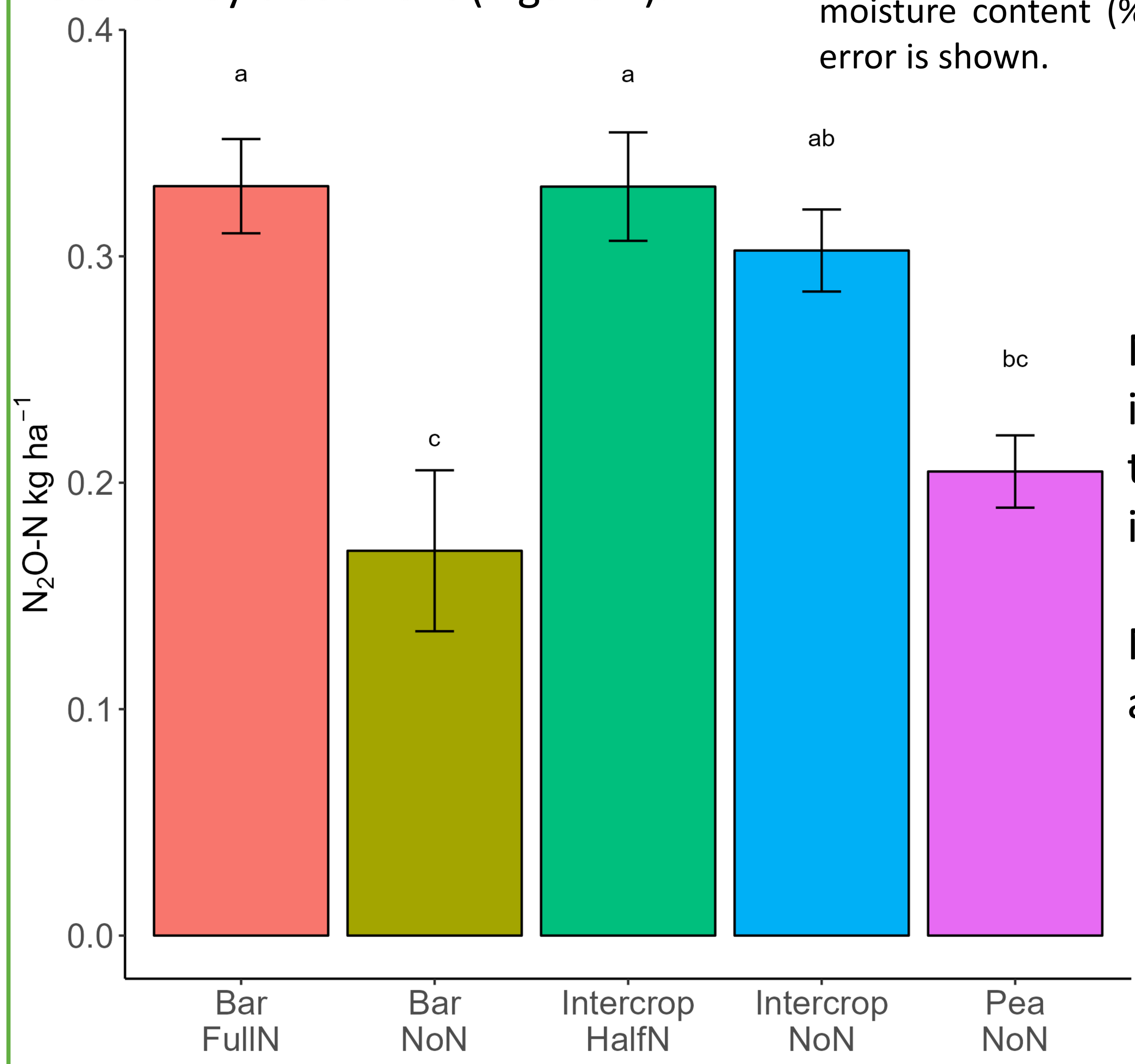

Figure 4 – Cumulative emission of N_2O in first 21 days

No difference in N_2O emission between intercropped barley/pea with no N and the full-rate barley or half rate intercrop (Figure 4).

No yield data yet but visible differences are evident (Figure 5)

Expectations

The effect of the cropping systems will become more evident as the experiment continues. Full crop cover is not achieved in the first 21 days and that is especially true for the peas.

Figure 5 – Yield plots for all treatments approximately one week before harvest.

Conclusions

- Pea has not lowered but raised the emission of N_2O so far.
- No significant difference between the N_2O emission from sole-barley with full rate of N-fertiliser and the intercrop with half-rate of N-fertilizer or the half-rate intercrop.
- Further data required to fully evaluate the impact of intercropping.

INTERCROP VALUES

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862357

Can plant – soil interactions be a controller on GHG emissions from soils?

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The James Hutton Institute

Introduction

Plant-soil interactions play an important role in regulating greenhouse gas emissions (CO_2 and N_2O) and in the storage of carbon (C) as soil organic matter (SOM) creating the potential for crop selection to be a tool for mitigating climate changing and improving soil health. This is relevant across all crops and cropping systems but is of particular importance in grassland soils which are known to be important stores of C. However, there is still a need to understand which plant traits drive differences in the rates and products of C cycling and how this is regulated by the soil microbiome which mediates all soil nutrient cycling processes.

Microbial communities are central to the regulation of soil functions consequently, soil communities influence greenhouse gas (GHG) emissions, soil C storage and nutrient availability by regulating the biogeochemical processes that determine the fate of C in soils. Understanding the structure and function of soil communities associated with plant roots is therefore critical to understanding how crop selection can help soils be managed for multiple benefits.

The aim of this research is therefore to characterise plant-driven soil microbial community selection across a range of agricultural grasses, and to assess the extent to which distinct microbial community compositions were predictive of CO_2 emissions from soil.

Acknowledgements
Thanks to Pete Hedley and Jenny Morris for support with next generation sequencing. This work was funded by the Rural and Environment Science and Analytical Services Division of the Scottish government as part of the 2016-2022 and 2022-2027 Strategic Research Programme under Research Deliverable 1.1.1 Soil and its Ecosystem Function and D3 Healthy Soils.

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Methods

A microcosm experiment used to investigate the interaction between grass variety, microbial communities and CO_2 emissions. Microcosms (Fig 1.) were planted with one of 10 different grass varieties, representing 5 different grass species (Table 1) and fertilised with NH_4NO_3 at an agriculturally relevant rate (60 kg N ha^{-1}).

When the grass had germinated, microcosms were sampled weekly for CO_2 over a 6-week period. CO_2 efflux was measured from grass free headspaces using an Environmental gas monitor (PP systems, Amesbury, USA).

At 6 weeks, microcosms were destructively sampled and microbial communities characterised using next generation sequencing. 16SrRNA amplicon libraries were created and sequenced using the Illumina Miseq. Qiime2 with DADA2 plugin was used to determine amplicon sequence variants (ASV). Differences in community composition was visualised using PCoA and associations with CO_2 tested using Canonical analysis of principal coordinates (CAP).

Fig. 1 Microcosm design and CO_2 collection.

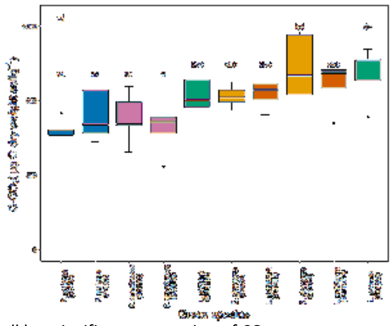
Table 1 List of the 5 different grass species and 10 different grass varieties used in this study.

Grass Species	Grass variety
Lolium perenne	Seagoe
Lolium perenne	Solomon
Phleum pratense	Presto
Phleum pratense	Comer
Festuca arundinacea	Barelite
Festuca arundinacea	Borneo
Dactylis glomerata	Sparta
Dactylis glomerata	Donata
Lolium multiflorum	Muriello
Lolium multiflorum	Barmultra

Results

Cumulative CO_2 emissions differed between grass varieties ($p<0.001$) (Fig.2a), with all grasses except Barelite producing more CO_2 than the control. There was a linear relationship between cumulative CO_2 emissions and grass biomass ($r^2 = 0.21$, $P < 0.001$).

Across all samples a total of 13991 unique ASVs were detected of which 5182 were found in more than one microcosm. Structure of microbial communities differed both between grass species ($p < 0.001$) and grass varieties ($p < 0.05$) (Fig 2b.).



CAP found that microbial community structure was associated with a small but significant proportion of CO_2 emissions independent of the effects of grass variety (9%, $p < 0.05$). This increased to 10% ($p<0.05$) when DOC concentrations were included in the model with communities associated with high DOC concentration associated with low CO_2 emissions (Fig 2c.).

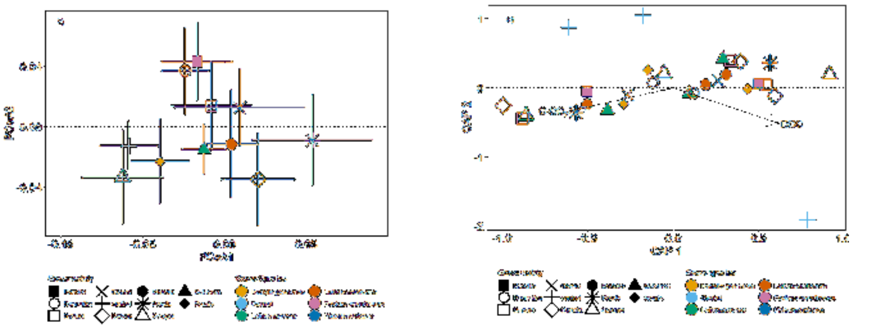


Figure 2 a) Cumulative CO_2 emissions for each of the 10 different grass varieties included in this study and the unplanted control. Grasses with the same letter are not significantly different from each other (p> 0.05).b) PCoA using relative abundance sequence data. c) CAP analysis of relative abundance data with grass variety as a conditional variable and CO_2 emissions and DOC as constraining variables.

Conclusions

- The selection of grass variety for cultivation has the potential to be an important tool for managing soil C storage and CO_2 emissions in grassland soils.
- Different grasses selected for their own unique microbial communities and the composition of these communities had a small but significant effect on CO_2 emissions from soils.
- This provides insight into the potential mechanisms by which grass selection may control the partitioning of C into soil, plant and atmospheric pools and highlights the important role crop selection may play in mitigating climate change and improving soil health.

Growing hemp in Scotland: Impact on soil health and Crop Yield

Madalina Neacsu[1], Nicholas Hayward[1], Wendy Russell[1] and Lorna Dawson[2]
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2. James Hutton Institute, Aberdeen. AB15 8QH

Introduction

Scotland's ambitious target of net-zero GHG emissions by 2045 calls for a holistic approach across industry, research, education and government, as well as changing individuals' behaviour. Increasing agricultural diversity by inclusion of crops such as hemp could be a key component in the sectors response towards the mitigation of GHG emissions. As well as the nutritional and fibre benefits of hemp, it brings environmental advantages due to its capacity for carbon sequestration, contribution to greater biodiversity, land recovery and remediation. Agricultural hemp could become a new 'cash-crop' for Scottish agriculture and play a role in the development and expansion of a low carbon environmentally responsible industry, bringing and creating new opportunities across the supply chain.

Aim

This pilot study started in 2023 and is collecting data on soil health and crop yield and nutritional quality at three Scottish Farms to explore the possibility of introduction of hemp as a rotational (break crop) crop in Scotland.

Methods

From 2021, eleven different farms were growing agricultural hemp for seed in Northeast Scotland (Figure 1) for the very first time and in 2022 the first Scottish commercial hemp oil was produced. Three of these farms provided samples for this pilot study (Figure 1).

The first set of soil samples were collected in Spring and Autumn of 2023 after one season of growing hemp and the second set collected in Spring 2024 after one season of growing hemp (Hemp Fields; Figure 1). The Spring 2024 soil samples were compared with soil after growing a cereal crop in the same year at the same farms (Control Fields; Figure 1). Farm 1 and 3 had variety Finola and Farm2 Estica (Field 1) and Finola (Field 2).

The soil samples were measured for their carbon content (C%), nitrogen content (N%), percent moisture loss, loss on ignition (LOI) at 450 ºC and 900 ºC, mineral content, pH, and content of plant growth hormones using established methods (1, 2).

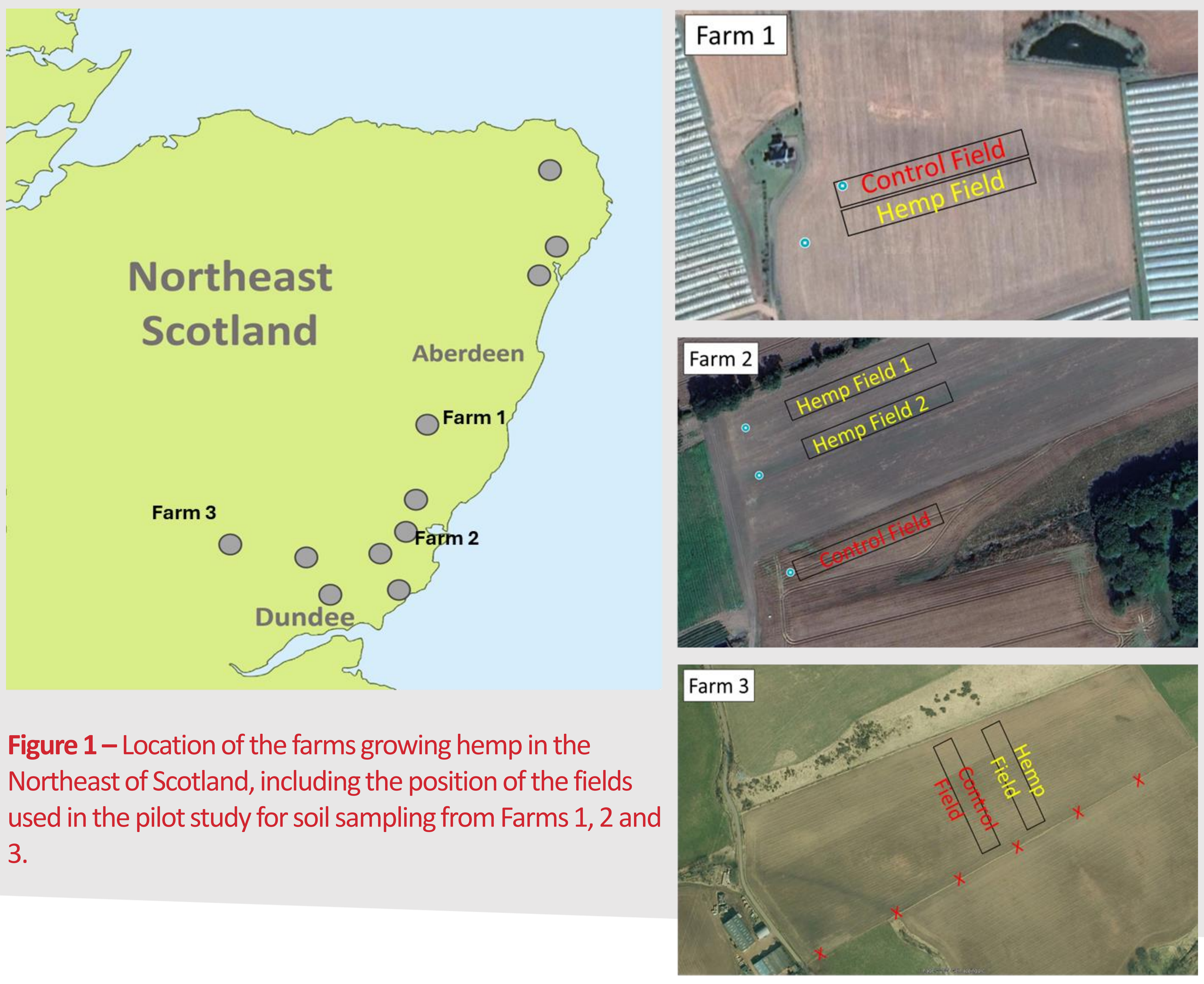

Figure 1 – Location of the farms growing hemp in the Northeast of Scotland, including the position of the fields used in the pilot study for soil sampling from Farms 1, 2 and 3.

Results

Following hemp production at all farms, there was an increase in soil pH levels from spring to autumn 2023. For two farms the increase was significant (Figure 2 A). The LOI at 450 ºC and 900 ºC also showed significant increases from spring to autumn 2023 on all farms (Figure 2 B).

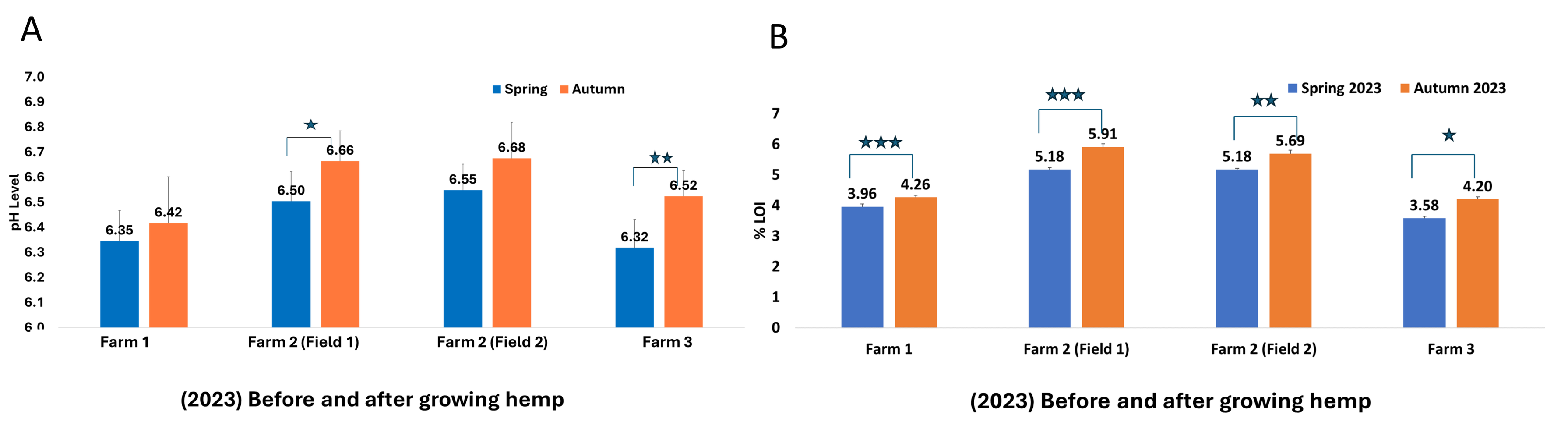

Figure 2 – Average pH values (n=7; mean ± stdv) of soil samples measured in spring 2023 (before hemp sowing) and autumn 2023 (after hemp harvest) (A); Average Loss on Ignition at 450 °C of soil samples measured in spring 2023 (n=3; mean ± stdv) (before hemp sowing) and autumn 2023 (n=4; mean ± stdv) (after hemp harvest) (B). Where, (*- p<0.05; **- p<0.01 and ***- p<0.001).

Comparing the soil samples collected after growing hemp and a cereal crop on the same farm in the same year, it was show that the percentage of Soil Nitrogen (%N) and the percentage of Soil Organic Matter (%SOM) was significantly increased following hemp production in two out of the three farms, (Figure 3 A, B); and the Carbon to Nitrogen ratio was significantly reduced and the LOI at 450 ºC and 900 ºC was significantly higher in two out of three farms, following hemp production (Figure 3 C).

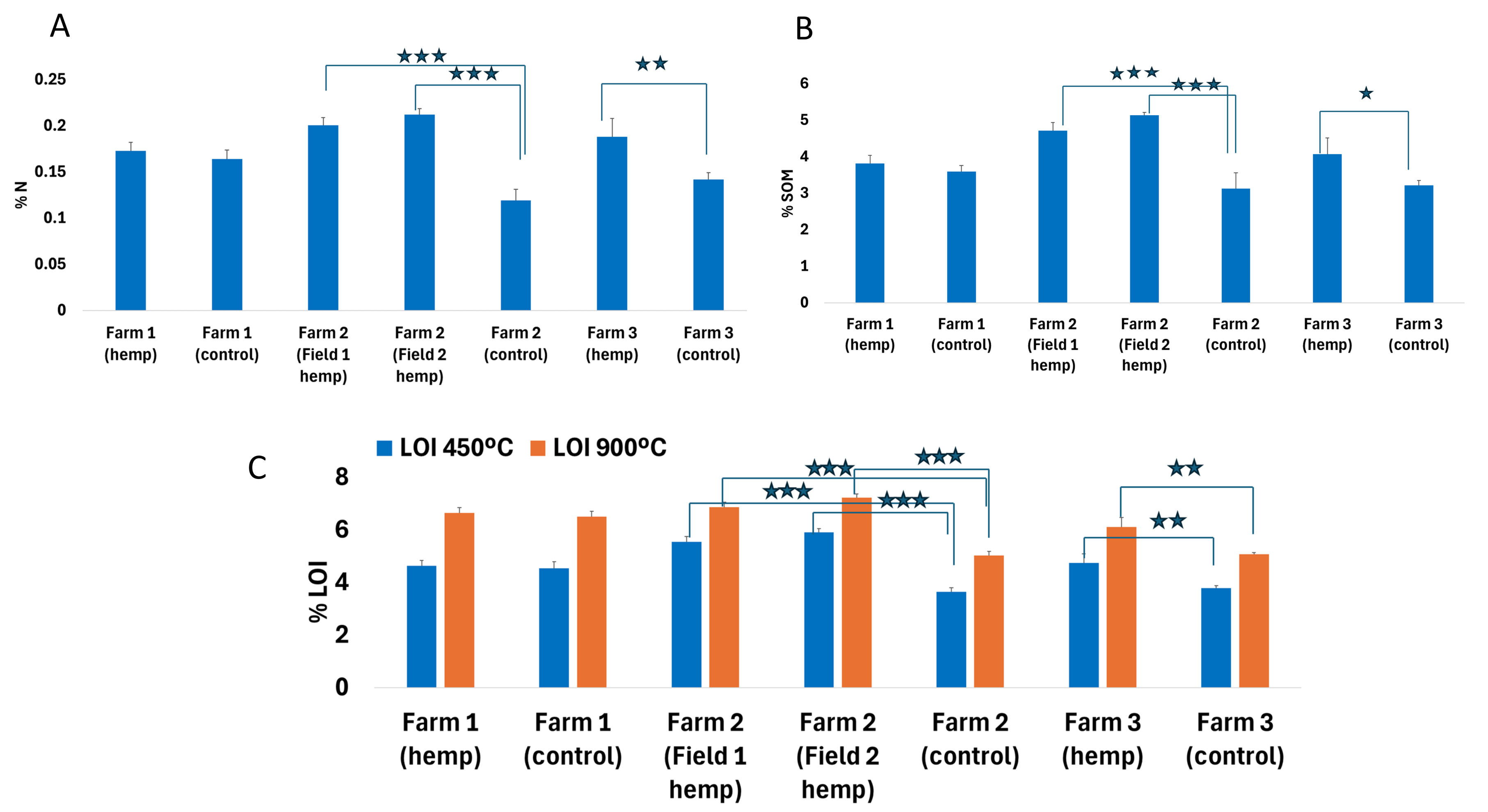

Figure 3 – Percentage of Soil Nitrogen (%N) (A), Soil Organic Matter (%SOM) (B) and Loss on Ignition (LOI) at 450 ºC and 900 ºC (C) (n=4; mean ± stdv) of samples collected from fields following hemp and respectively a cereal crop production. Where, (*- p<0.05; **- p<0.01 and ***- p<0.001).

Preliminary conclusions and planned future work

- These preliminary findings suggest that hemp could potentially enhance soil health and support its inclusion as a rotational crop, sustaining the implementation of a larger scale agricultural trial including the soil physical and biological characteristics.
- Further assessments of the impact of hemp on the yield and nutritional value of a subsequent cereal crop, and the impact on the soil characteristics will also be assessed as part of this study.

Acknowledgement

This work was funded by the Scottish Government's Rural and Environment Science and Analytical Services (RESAS) Strategic Research Programme 2022–2027 (project RI-B1-1). Special thanks to the farmers who took part in this study and supplied the soil samples and to the Analytical Department from The Rowett Institute and the James Hutton Institute for their help with samples analysis.

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(2) https://www.sfu.ca/geog/soils/lab_documents/Estimation_Of_Organic_Matter_By_LOI.pdf

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Large-scale and Systems Modelling

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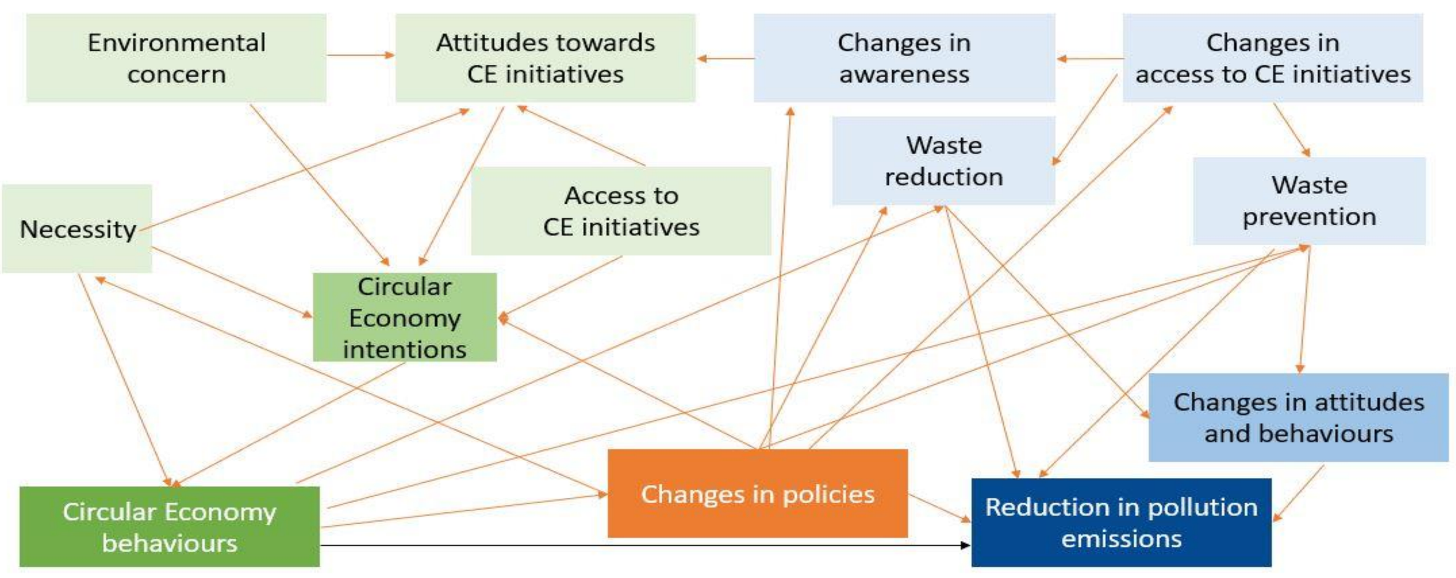
The BioSS SRP project "Large-scale and Systems Modelling" project is developing a powerful set of tools to better support decision-making related to key 21st century systems challenges. These include climate change, the biodiversity crisis, and building a restorative economy. Key applications highlighted in this poster include: modelling of circular economy dynamics to aid the green recovery in Scotland; design of statistical tools to aid model design, parameter fitting, and computational efficiency for complex ecological models; the development of digital twins of real-world livestock trading systems, and the role of farmer trading behaviour on the success of endemic disease control scenarios; and assessing the adaptive potential of Scottish forests under climate change.

BioSS

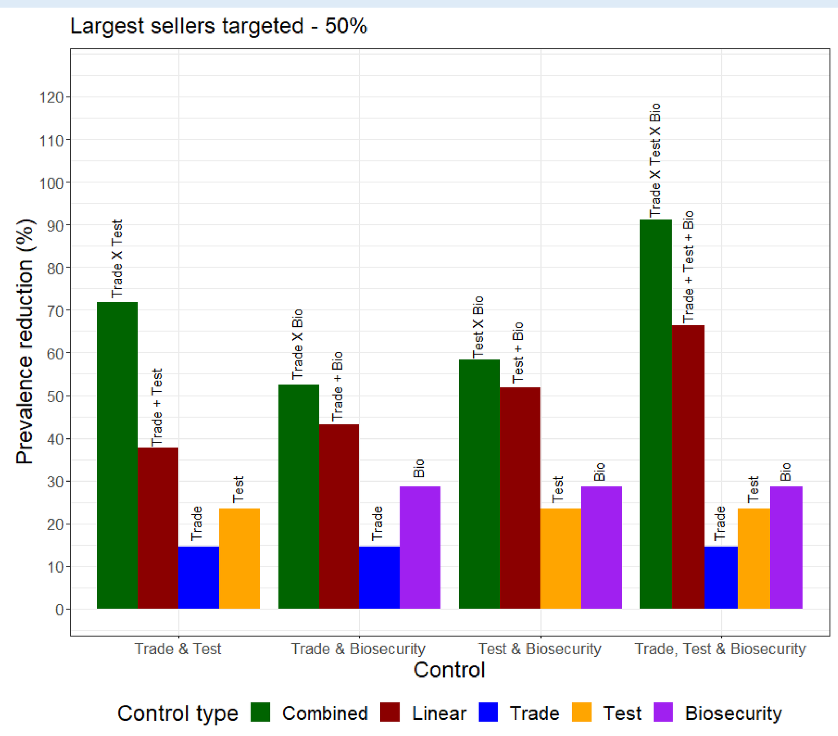
Causal inference for circular economy data[1]



- Moving towards a circular economy requires changing the complex patterns of use, waste, and emissions.
- These involve links between economic, environmental, socio-cultural, and institutional processes. At the individual level, patterns of behaviour are equally complex and interconnected.
- Thus, understanding causal relationships is vital to revealing the changes in behaviour that lead to sustainable outcomes.
- We propose a causality framework in the context of sustainable behaviours that reflects a more comprehensive picture of this complex system. This will help accelerate the green recovery in Scotland.

Impact on policy & practice: With JHI colleagues, Scottish data will be analysed to inform policy makers on attitudes and perceptions in an effort to promote circular economy behaviours and practices.

Developing digital twins of the Scottish cattle trade industry[3]



- The Scottish cattle trading industry is a complex, dynamic system in which individual farm trading behaviours give rise to large, time-varying networks.
- Trade also facilitates the spread of disease, leading to endemic persistence.
- As such, understanding the behavioural drivers which lead to observed trading patterns is vital in controlling disease.
- Leveraging large-scale trading data for Scotland, we have developed an Agent-Based digital twin of the Scottish cattle trade industry.
- This model has been used to identify key farms responsible for disease spread, the effectiveness of trade-based controls, farm-level behavioural adaptation in response to controls, and how these adaptations can amplify the effectiveness of traditional control measures.

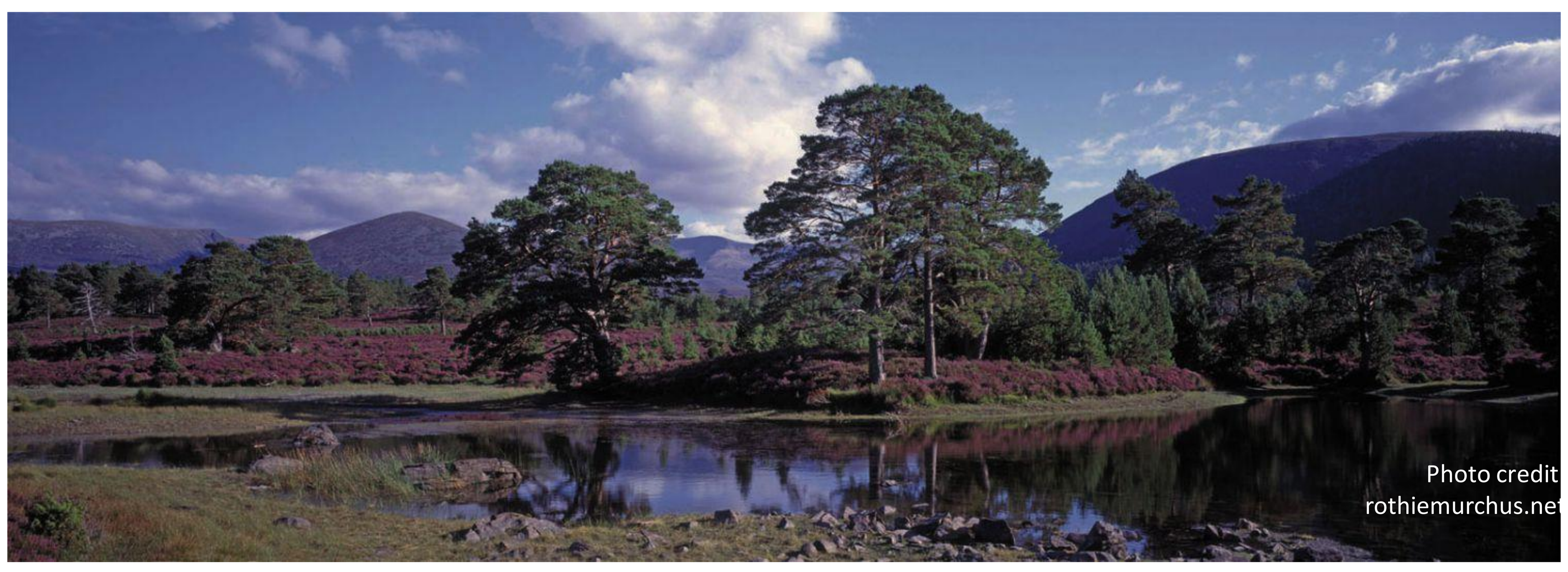
Impact on policy & practice: With SRUC colleagues, data provided by Premium Cattle Health Scheme is being used to apply a digital twin of Scottish cattle trading to Johne's disease.

Statistical analysis of complex simulation models[2]

- To study complex dynamic processes, such as the change of phosphorus levels in streams over time, sophisticated simulation models, Simulators, have been developed.
- These can be uses to predict the effects of management actions and climate change.
- However, complexity comes at a cost: identification of which components have the most effect can be difficult, parameter fitting can be challenging, and computation time can be high.
- This work strand is applying components of DACE (Design and Analysis of Computer Experiments) to Simulators used by scientists at JHI and SRUC to combat these issues.
- By developing novel approaches for Sensitivity Analysis, History Matching, and Emulation.

Impact on policy & practice: Uncertainty tools were applied in Emerging Water Futures project to improve modelling for flood and drought forecasting for SEPA and Scottish Water.

Assessing adaptive potential of Scottish forests[4]



- Natural & human systems, including forestry, face unprecedented environmental change. Management requires better understanding of adaptive potential of species & ecosystems.
- Genomic tools are being applied to quantify adaptive potential of Scottish Scots Pine (*Pinus sylvestris*) populations – a culturally significant keystone species. This information is being combined with theory from quantitative population genetics to develop models to assess adaptation of Scots Pine under scenarios of climate change.
- This enables addressment of the key **forestry management challenge**: **local adaptation versus assisted migration under climate change.**

Impact on policy & practice: this project is informing work under *NERC's Future of UK treescapes* programme.

RESAS Rural & Environmental Science and Analytical Services | gov.scot | SEFARI | The James Hutton Institute

Large-scale and Systems Modelling@BioSS is also: developing state-of-the-art tools to infer models from data; modelling species level vegetation dynamics e.g. applied to management of peatlands; understanding how behaviour impacts large-scale uptake of integrated pest management; building dynamic models to understand persistence of AMR; and developing statistical methods for soil mapping e.g. applied to quantify peatland area under converted grassland and associated emissions – **Please contact** helen.kettle@bioss.ac.uk **for more details**

[1]Altea Lorenzo-Arribas, [2]Ken Newman, [2]Adam Butler, [3]Martin Knight, [4]Chris Pooley, [4]Stephen Catterall & [3,4]Glenn Marion

Improving biosecurity resources for professional operators

Project lead: Dr Matt Elliot, Plant Health & Biosecurity Scientist (RBGE)
Project partner: Alistair Yeomans (Plant Health Alliance).

ROYAL BOTANIC GARDEN EDINBURGH | Plant Healthy | Plant Health Centre – Scotland's Centre of Expertise | Scottish Government Riaghaltas na h-Alba gov.scot

Introduction

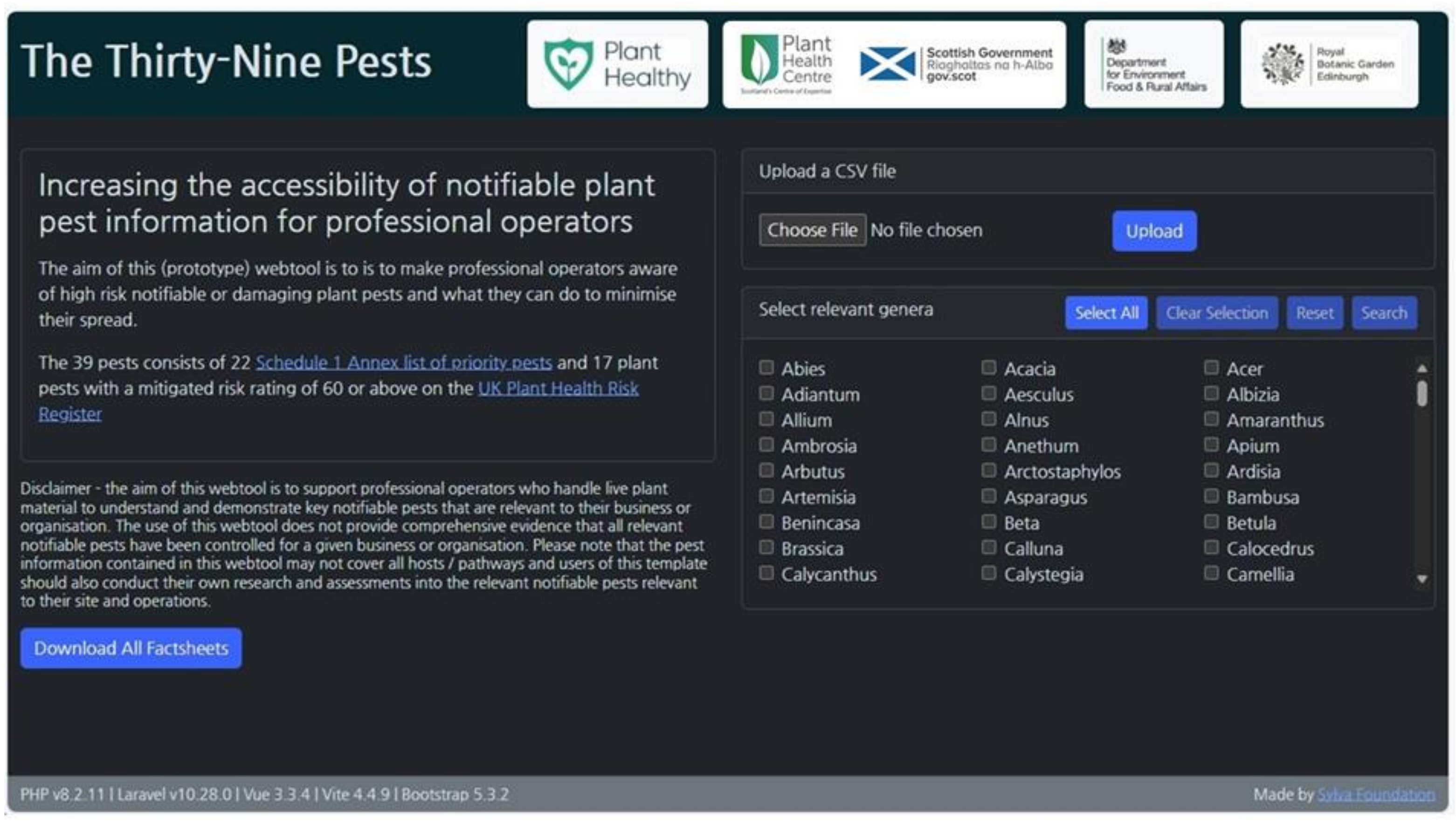
- Professional Operators (those who move / handle / sell plants) have a regulatory responsibility to meet certain requirements when issuing Plant Passports (i.e. article 89 - *Authorisation of professional operators to issue plant passports* of the retained EU regulation 2016/2031).
- However, finding plant pest and disease information required to carry out these responsibilities is difficult due to the plethora and complexity of information available.
- Some Professional Operators are thus struggling to meet regulatory requirements.
- Presenting accessible, clear information on key plant pests will improve site pest risk management plans, improve supply chain biosecurity and in doing so help protect GB's ecosystems.

Objectives

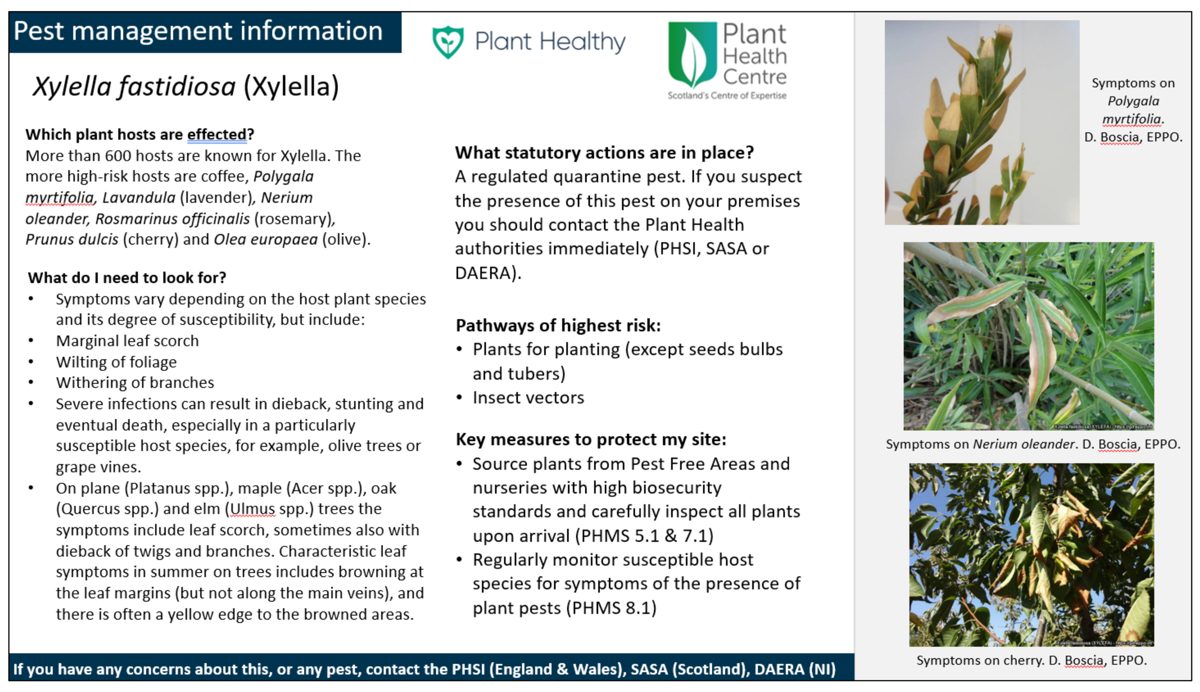
- Produce a prototype webtool which assists Professional Operators to conduct pest risk analyses of the highest risk notifiable plant pests, thereby ensuring that they meet the requirements of article 89.
- Ensure that the Plant Health Management Standard fully supports businesses and organisations establish effective *Pest risk management plans* and thereby meet article 91 (retained EU regulation 2016/2031).

Project outcomes

- 39 relevant plant pests were selected – the 22 UK priority plant pests plus another 17 plant pests with a mitigated risk-rating of 60 or above on the UK Plant Health Risk Register (as of Oct 2023). This range of pests covers most types of plant pest – i.e. insects, nematodes, fungi, bacteria and viruses.
- A prototype webtool was produced where a user can upload a plant stocklist or select the relevant plant species from the list:



- The tool then presents the user with the relevant pest information sheets based on their selections, for example:


Pest management information

Plant Healthy | Plant Health Centre – Scotland's Centre of Expertise

Xylella fastidiosa (Xylella)

Which plant hosts are effected?
More than 600 hosts are known for Xylella. The more high-risk hosts are coffee, *Polygala myrtifolia*, *Lavandula* (lavender), *Nerium oleander, Rosmarinus officinalis* (rosemary), *Prunus dulcis* (cherry) and *Olea europaea* (olive).

What do I need to look for?
- Symptoms vary depending on the host plant species and its degree of susceptibility, but include:
- Marginal leaf scorch
- Wilting of foliage
- Withering of branches
- Severe infections can result in dieback, stunting and eventual death, especially in a particularly susceptible host species, for example, olive trees or grape vines.
- On plane (Platanus spp.), maple (Acer spp.), oak (Quercus spp.) and elm (Ulmus spp.) trees the symptoms include leaf scorch, sometimes also with dieback of twigs and branches. Characteristic leaf symptoms in summer on trees includes browning at the leaf margins (but not along the main veins), and there is often a yellow edge to the browned areas.

What statutory actions are in place?
A regulated quarantine pest. If you suspect the presence of this pest on your premises you should contact the Plant Health authorities immediately (PHSI, SASA or DAERA).

Pathways of highest risk:
- Plants for planting (except seeds bulbs and tubers)
- Insect vectors

Key measures to protect my site:
- Source plants from Pest Free Areas and nurseries with high biosecurity standards and carefully inspect all plants upon arrival (PHMS 5.1 & 7.1)
- Regularly monitor susceptible host species for symptoms of the presence of plant pests (PHMS 8.1)

Symptoms on *Polygala myrtifolia*. D. Boscia, EPPO.

Symptoms on *Nerium oleander*. D. Boscia, EPPO.

Symptoms on cherry. D. Boscia, EPPO.

If you have any concerns about this, or any pest, contact the PHSI (England & Wales), SASA (Scotland), DAERA (NI)

- This enables the user to understand and assess the risks associated with the notifiable pests and diseases specific to the plant species they are trading.

Key messages

- With over 1,400 plant pests on the UK Plant Health Risk Register it can be challenging for Professional Operators to know where to start when identifying the notifiable plant pests that are relevant to their business or organisation.
- This project successfully produced a prototype webtool which enables users to assess and understand the notifiable pests that are relevant to the plants that they are trading. This is an important element of biosecurity, lowering the pest risk to GB businesses and wild landscapes.
- This webtool can now be incorporated into the suite of information which Plant Health Authorities provide to Professional Operators, e.g., on Defra's Plant Health Portal.

Acknowledgements

This work was funded by the Scottish Government's Rural and Environment Science and Analytical Services (RESAS) Division through the Centre of Expertise for Plant Health with supporting funding from Defra.

Forest Research | ROYAL BOTANIC GARDEN EDINBURGH | The James Hutton Institute | SRUC | CPHOS Chief Plant Health Officer for Scotland | SEFARI LEADING IDEAS FOR BETTER LIVES

Do the Scottish public value NHS outdoor spaces?

Estimating the health and wellbeing value of the NHS outdoor estate

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Logos of collaborators

Public Health Scotland | University of Aberdeen | NatureScot NàdarAlba

Introduction

Urban heat has been identified as one of the most serious effects of climate change and urban areas will need to adapt using various measures such as the provision of more green, blue and open spaces[1]. There is a large body of evidence showing greenspace exposure has a positive effect on health and wellbeing[2,3]. Many NHS facilities provide such spaces, however, understanding the monetary value placed on these spaces by the Scottish public will demonstrate if such spaces are subsequently valued. This highlights to policymakers what NHS estates are being valued thus providing examples of good practice in provision of green space.

Research questions

How are NHS outdoor spaces used?
What is their health and wellbeing value to different users?
What is the value to the Scottish public?

Methods

This work has created surveys based on non-market valuation to obtain monetary values for NHS Scotland outdoor spaces. These surveys are being completed by a representative sample of the Scottish population (approximately n=2,538).

This work will generate values based on contingent valuation and the Office for National Statistics's exposure method for different users and non-users. An average monetary value will be generated for local primary care sites (if this has an open space) and local hospital sites. The values should be interpreted as the total economic value (which includes health benefits) of the respondents local NHS sites – with the caveat that there is great heterogeneity between them. As with all non-monetary valuations, it is very difficult in practice to disentangle the health benefit from the total value

Figure 1 – room for a graphic: *Outdoor space in the Foresterhill Campus (opposite Aberdeen Royal Infirmary with the University of Aberdeen's Suttie Centre in the back)*

Results

The survey is currently being answered by the Scottish representative sample and the results will be arriving shortly.

We will estimate and explore the monetary value and the health and wellbeing value of the NHS outdoor spaces to different users/non-user:

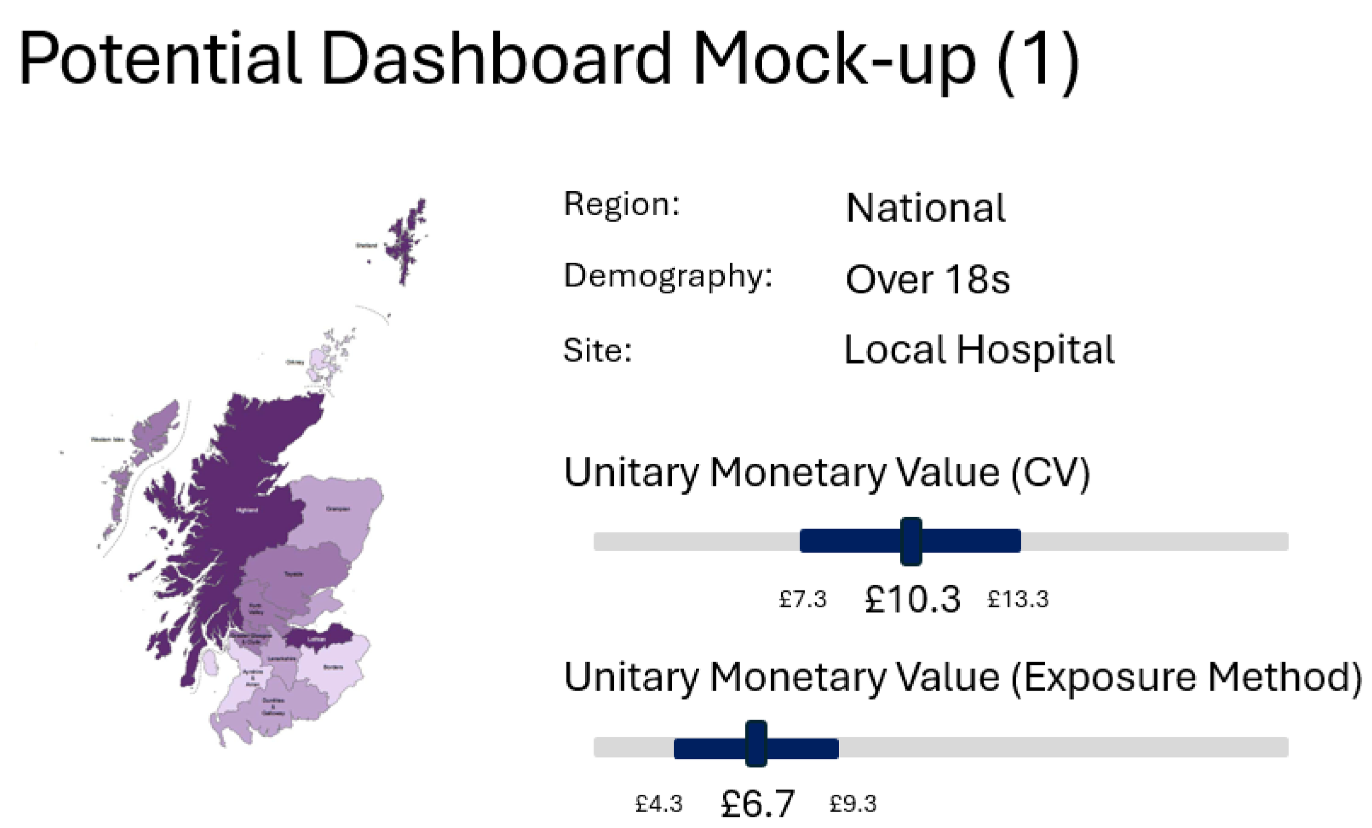
- positive values are a result of direct use of sites/option to use sites/value to others.
- negative values are a result of not caring/not perceiving value/not using.

Next steps

The data from the survey will be collected and analysed to estimate the monetary value placed on different NHS sites' open spaces and allow for estimation Quality Adjusted Life Years (QALY) potentially gained from site use.

PHS will then create a dashboard detailing the data by healthboard area and is envisioned to look similar to Figure 1.

Figure 1 Next steps for creating dashboard



Conclusions

The results will provide information on whether, and how much, the Scottish public value NHS open spaces.

The results will also be useful for NHS Scotland with regards to the following areas:

- **Describe how NHS open spaces are used in specific sites**
- **Explore potential use of NHS open space:**
  - Reasons why open spaces are not used
  - Explore next best alternative (substitute) recreation site use

Acknowledgement

Special thanks to Jodi Dean, Michelle Wilson Chalmers, Charles Bestwick, Ivan Clark and Pete Rawcliffe

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A Scottish register to tackle One Health and foodborne infections

SRUC

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Introduction

Scotland has an international reputation for microbiology in relation to food safety. The work is genuinely within the One Health remit, spanning microbes associated with humans, plants, animals and the wider environment. The question is how do we draw all of the information together so it can be used in a beneficial way to aid with foodborne and other One Health pathogens going forward.

We have secured a UKRI-funded policy fellowship to address this question, working with the Chief Science Adviser, Prof. Julie Fitzpatrick. The work is directly relevant to new and ongoing biosurveillance initiatives including the FSA-led Pathogen Surveillance in Agriculture, Food and Environment (PATH-SAFE) programme for detection and tracking of foodborne disease (FBD) and antimicrobial resistance (AMR). It is developing a genomics platform to support research and epidemiology (Fig. 1). PATH-SAFE aligns with the Biosurveillance Network, part of the National Biosecurity Strategy launched by UK government in June 2023. Parallel initiatives have been established for animal and plant pathogens, and for environmental monitoring. PATH-SAFE is supported by multiple agencies including Food Standards Scotland, supporting use of whole genome sequencing to understand food source attribution, infection threat, and the level of AMR in *E. coli*.

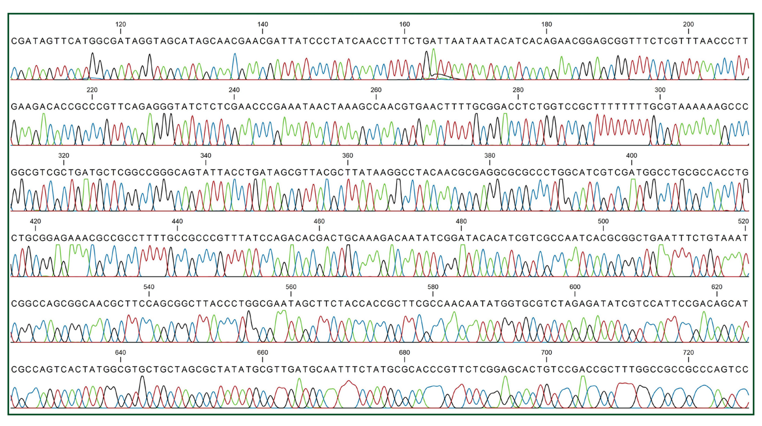

Figure 1A: DNA sequence (SRUC)

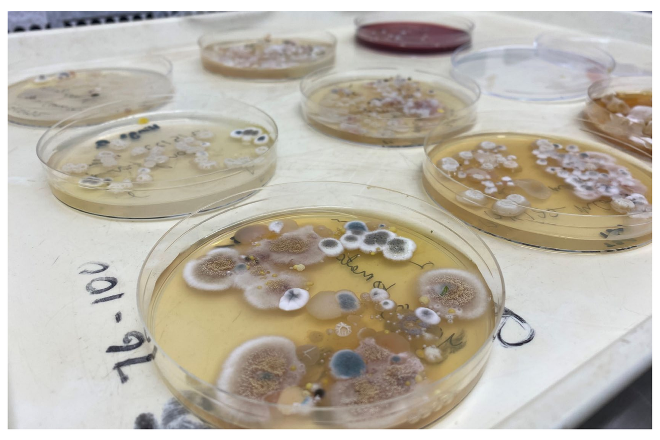

Figure 1B: Microbiology cultures (SRUC)

Approaches

Our aim is to understand Scotland's biological assets of expertise and resources, in relation to One Health-relevant infectious diseases. Where applicable, the resource includes genomic sequence, as it is a key feature for infectious disease investigations.

We are gathering information from across Scotland spanning One Health-relevant areas. These include 71 laboratories and facilities within the public sector (Fig. 2) as well as facilities in the academic and applied research sector, and commercial organisations that generate shareable culture collections.

Figure 3: Locations of public sector laboratories in Scotland (Julie Fitzpatrick)

Figure 1C: Representation of pathogen genomic comparison

Data management

A key consideration to generate a centralised and accessible resource is data management. Multiple types of data are provided by multiple users, each with different priorities and requirements. Therefore, a data sharing policy is being implemented to ensure security and trust whilst maintaining accessibility according to the FAIR principles. Our data governance is being advised by data managers who already work with genomics datasets, culture collections and public heath data.

Benefits of a One Health infectious disease register

Agriculture and food production is an economic and strategic strength in Scotland, with global recognition of excellence in Scottish produce. We are able to enjoy a high level of food safety because there is extensive expertise and biological resources on infectious diseases, with strong connectivity between public, animal, plant and environmental health agencies, and biological research. But we need to keep up with the food system changes driven by major challenges like climatic change, geo-political changes, non-communicable disease burdens, coupled with agri-food technological and management innovations.

We have already shown how the infectious disease expertise can pivot to respond to the global threat of the COVID-19 pandemic, providing laboratory facilities and public health expertise. Scottish Government continues to strengthen our resilience against future shocks. Collating the information into a central One Health infectious disease register will improve the response time for emerging disease threats as well as the collective knowledge about the assets. It will help to keep Scotland at the forefront of public heath science for foodborne and One health-relevant threats.

Acknowledgements

This work is funded by UKRI (BBSRC) on the 2023 cohort of policy fellowships, hosted by the Scottish Government Central Analysis Division. It is linked to SRUC projects funded by Scottish Government RESAS Strategic Research Programme on Food Safety (B6), for STEC and AMR. Data governance is linked to a SRUC project funded by BBSRC for a Biological and Bioinformatics Resource on the UK crop microbiomes and cryo-preservation.

UK CROP MICROBIOME CRYOBANK

RESAS
Rural & Environmental Science and Analytical Services

UKRI
Biotechnology and Biological Sciences Research Council

If you'd like to find out more or contribute to the resource please contact me:
Nicola Holden
Email SRUC: nicola.holden@sruc.ac.uk or at SG: nicola.holden@gov.scot

Turning the tide on potato viruses using data science and machine learning

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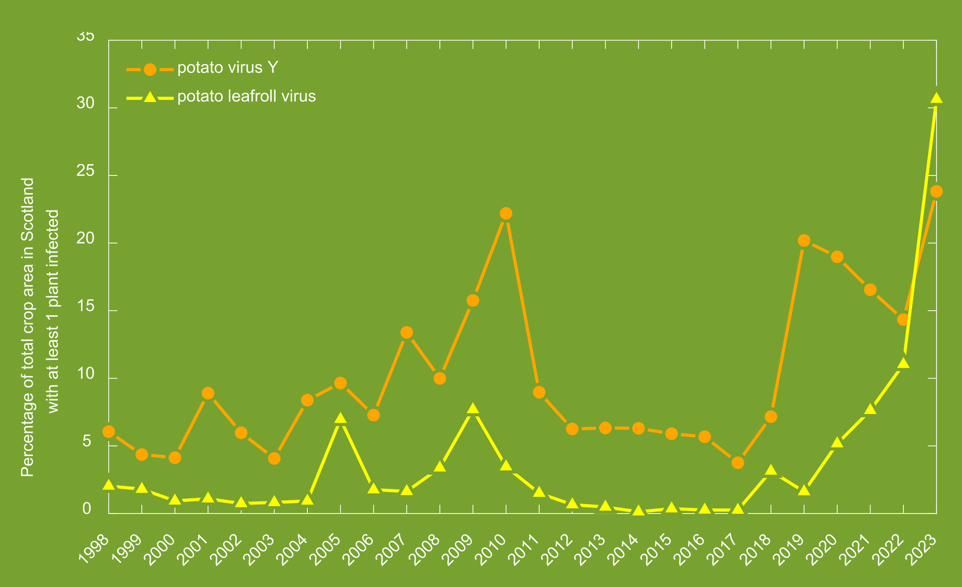
The James Hutton Institute

Introduction

Scottish seed potatoes are a premium global product, and the industry underpins UK potato production that is worth an estimated £4-5bn across all upstream and downstream sectors.

However, incidence of potato-infecting viruses, such as potato virus Y (PVY) and potato leafroll virus (PLRV), has been increasing across Scotland over the last five years, and this is an important concern for the sustainability of the industry:



All stages of seed potato production in Scotland are managed and administered under the Seed Potato Classification Scheme (SPCS), which is implemented and regulated by Scottish Government official plant health authorities (SASA), thereby ensuring complete traceability and quality assurance.

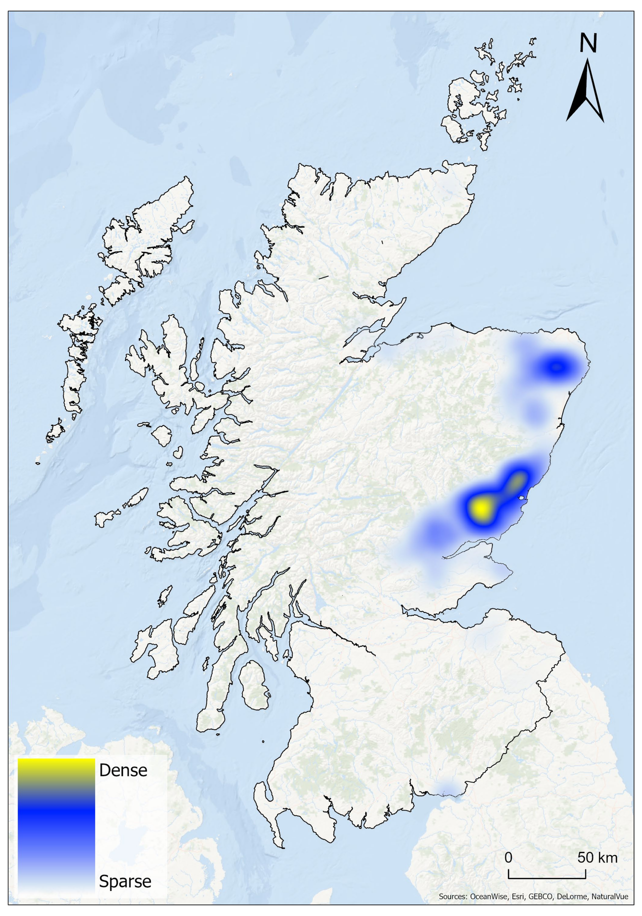
Under the SPCS, all growing seed potato crops are inspected 2-3 times a year for a range of faults, and this provides a rich source of data for analysis to inform industry and policy, and for the development of new models to guide decision-making for improved virus management.

Analysis of data from the Seed Potato Classification Scheme

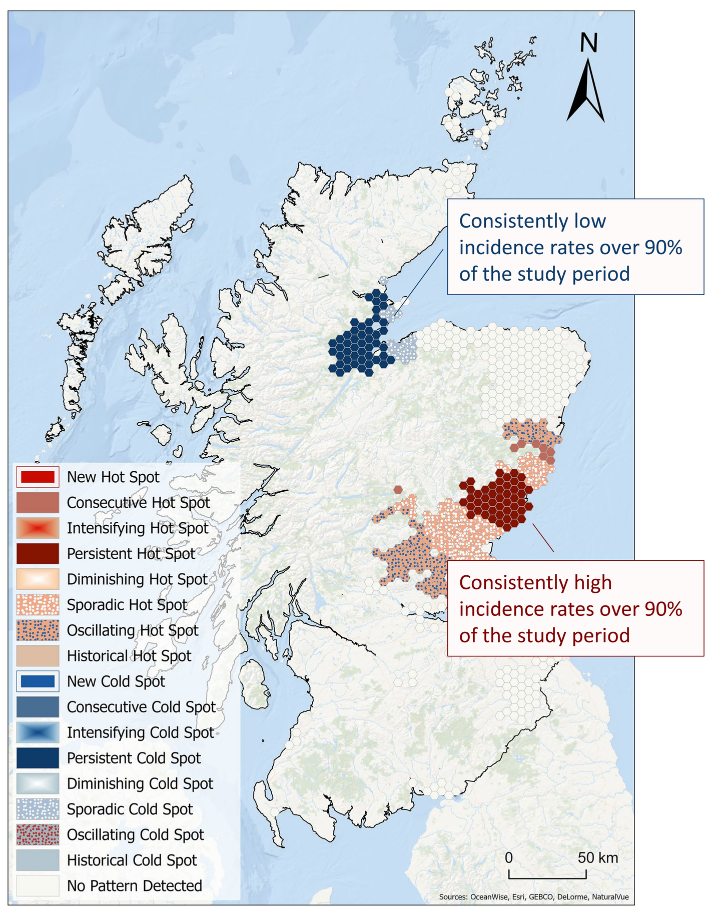
Data on 10 different potato viruses from over 100,000 crops (1998-2023) were analysed under the RESAS Strategic Research Programme, project JHI-A1-1 (Epidemiology of Key Pests & Diseases). This provided a new overview of the virus situation in Scotland:

	PVY	PLRV	PVA	PMTV	PVX	PVV	TRV	PVS	TBRV	PVM
Cara	19.9	50.6	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hermes	8.1	22.8	3.4	0.0	2.5	0.0	0.0	0.0	0.0	0.0
Maris Piper	30.8	39.2	0.0	0.4	0.0	0.0	0.0	0.0	0.8	0.0
Atlantic	39.5	16.1	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Desiree	35.8	30.9	1.6	0.0	2.4	0.0	0.0	0.0	0.8	0.0
VR 808	42.7	3.4	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0
Lady Rosetta	2.3	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Markies	2.4	24.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brooke	14.5	18.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Innovator	6.1	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Variety-specific incidence rates in 2023
Percentage of crops containing at least one infected plant for 10 different viruses for the top 10 most cultivated varieties. This provides up-to-date information on variety performance for growers.



Density of PLRV incidence in 2023
This provides up-to-date information that can be used to plan seed lot locations or varietal choices in the following season.



Spatiotemporal patterns of PVY incidence rates, 1998-2023
This reveals striking regional differences in long-term disease outcomes that can be used to inform policy, e.g., regional refinements to the SPCS or incentives for growers in hot-spots.

Development of warning systems for forecasting potato viruses

The above results were used to leverage additional funding from the Plant Health Centre to develop national- and local-scale models for forecasting PVY and PLRV, using machine learning applied to the SPCS data and aphid vector data.

National-scale models: performance of the best models for forecasting if total virus levels in Scotland in the upcoming season will be lower or higher compared to the average season:

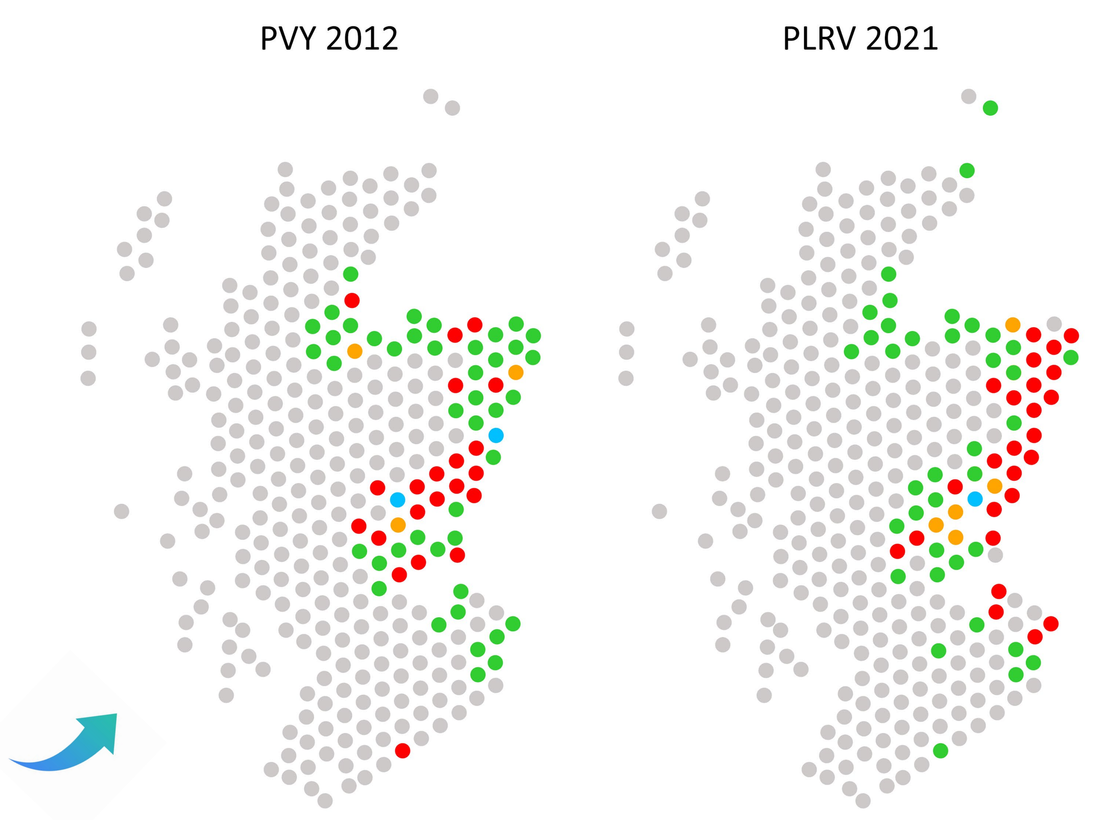
Virus & Algorithm	PPV	NPV	Accuracy
PVY: SVM	1	0.92	96%
PLRV: ANN	0.87	1	92%

PPV = positive predictive value = probability that a prediction of higher virus levels is correct
NPV = negative predictive value = probability that a prediction of lower virus levels is correct
SVM = Support Vector Machine
ANN = Artificial Neural Network

Local-scale models: performance of the best models for forecasting if gridded (250 km^2) virus levels in the upcoming season will be lower or higher compared to the average season for that grid cell:

Virus & Algorithm	PPV	NPV	Accuracy
PVY: RF	0.81	0.94	89%
PLRV: RF	0.86	0.98	94%

PPV = positive predictive value = probability that a prediction of a higher cell value is correct
NPV = negative predictive value = probability that a prediction of a lower cell value is correct
RF = Random Forest



Local-scale gridded predictions of PVY and PLRV for two example years
A negative prediction means that virus levels in the upcoming season will be lower compared to the average level for that grid cell, and a positive prediction means that virus levels will be higher.
Red = true positive, orange = false positive, green = true negative, blue = false negative.

Acknowledgements
This work was supported by funding from the Rural and Environment Science and Analytical Services (RESAS) Division of the Scottish Government under project JHI-A1-1 (Epidemiology of Key Pests & Diseases), and from the Centre of Expertise for Plant Health under project PHC2023_08 (Accurate Potato Virus Forecasts). Special thanks go to SASA, FERA, and the Rothamsted Research Insect Survey for data provision.

RESAS Rural & Environmental Science and Analytical Services
Plant Health Centre Scotland's Centre of Expertise
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SEFARI LEADING IDEAS FOR BETTER LIVES
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Policy implications

- Scottish seed potatoes still have high virus health, but a coordinated effort is required to flush virus out of our production systems.
- This research provides new and comprehensive information on the evolving virus situation in Scotland and the evidence required to develop solutions adapted to the industry's needs.
- The new warning systems for PVY and PLRV will enable data-driven decision-making on virus management that can strengthen the resilience of our seed and ware potato industries.
- The outcomes of this work will be used to update the white paper "Sustainability of Virus Health Management in Scottish Seed and Ware Potatoes" (Scottish Aphid-Borne Virus Research Consortium).

Building Public Health Resilience to Fluvial Flooding in Scotland

Dr Rhian Thomas[1] & Dr Claire Niedzwiedz[2]

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1 Background

Climate change is increasing our exposure to fluvial flooding in Scotland. Scotland's climate has seen a warming trend, shifting rainfall patterns, more extreme weather events and rising sea levels (Figure 1). Projected changes for Scotland's climate include:

- warmer, drier summers;
- milder, wetter winters;
- increases in intense, heavy rainfall events in summer and winter

These changes are happening faster than expected. Projected increases in intense heavy rainfall events will increase the risk of extensive and significant fluvial flooding in Scotland.

There is now clear evidence linking climate change to detrimental health impacts (WHO, 2021).

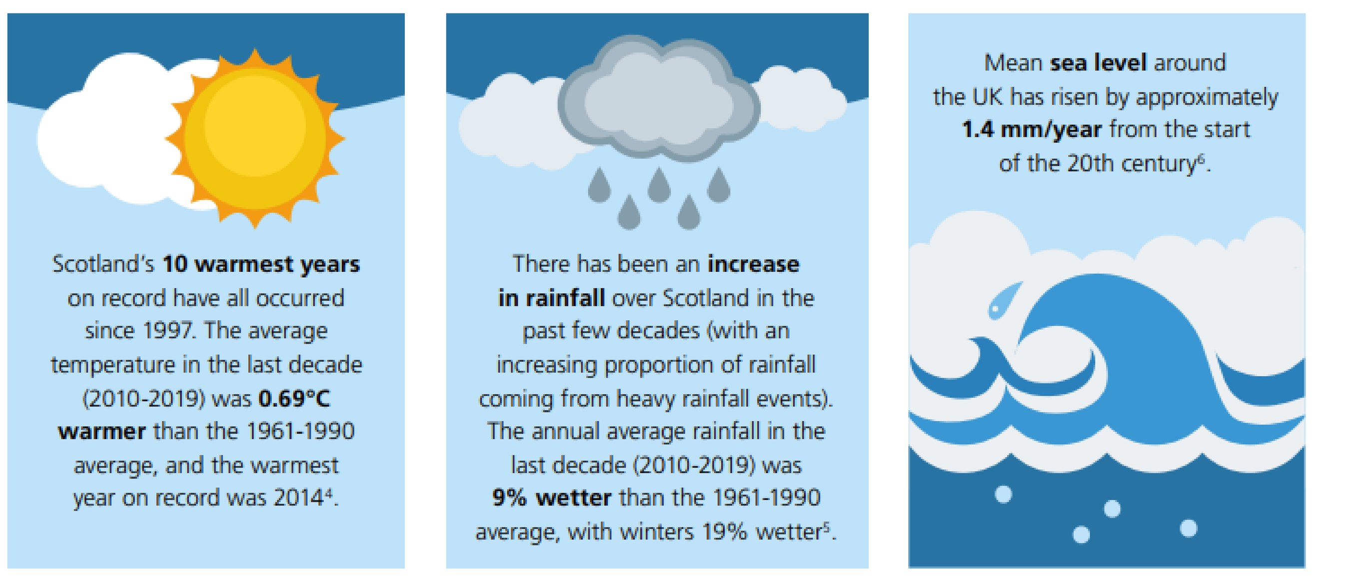


Figure 1. Adaptation Scotland: Climate Projections for Scotland Summary

2 Aims of CREW Science Policy fellowship:

To support evidence-based decisions by providing the opportunity for Scotland's research community to advocate for critical science that addresses upcoming water-related policy, regulatory and/or industry needs. This research supports the development of Scotland's first **Flood Resilience Strategy.**

3 Methods:

The research did this by synthesising existing literature and policies, via a rapid evidence assessment (REA) and a stakeholder workshop, identifying knowledge gaps, and providing future perspectives and recommendations to enhance individual and community health resilience to fluvial flooding.

4 What are the links between climate change and public health?

Physical (Box 1) and mental health (Box 2) are negatively impacted by flooding, with the greatest health impacts in the UK and Scotland seen for mental health. People who experience flooding are at higher risk of depression, anxiety and posttraumatic stress disorder. However, the longer term impacts of flooding on mental health have been less well described with limited evidence available to fully understand the impacts. **Secondary stressors** are factors indirectly associated with flooding that often have negative mental health consequences, but where potential action can be taken to reduce their impact (Box 3).

Box1 Physical Health Impacts of Flooding

- Drowning
- Electrocution
- Water-borne pathogens or chemical and/or biological contaminants arising from floods
- Skin and gut infections from exposure to contaminated flood water
- Vector-borne and zoonotic disease including rodent-borne disease
- Respiratory disease from mould and damp
- Cardiovascular events
- Non-fatal injuries
- Risk of carbon monoxide poisoning in clean-up phase from inappropriate use of generators

Box2 Mental Health Impacts of Flooding

- Anxiety and stress-related disorders
- Mood disorders including depression
- Post-traumatic stress disorder (PTSD)
- Strained social relationships, domestic violence
- Sleep disturbances
- Helplessness
- Fear and grief
- Suicidal thoughts and behaviours
- Alcohol and substance use
- Increase in psychotropic medication use
- Decrease in sense of self and identity via loss of place and grief reactions
- Emerging concepts such as ecological grief, eco-anxiety, solastalgia
- Exacerbation of pre-existing mental disorders

5 Who is most vulnerable?

Climate change affects everyone, but not equally. Climate change heightens existing social and economic inequalities. Exposure to floods interacts with demographic, socio-economic and environmental factors, as well as access to and quality of health care, to affect the magnitude and pattern of risks. Some groups are at greater risk of health effects due to flooding than others (Figure 2).

Health	Socioeconomic	Demographic	Geographic	Sociopolitical	Occupational
Chronic diseases	Poverty, financial insecurity	Age (elderly, children, adolescents)	Remote and dispersed communities	Gender	Healthcare and frontline workers
Physical, sensory or cognitive disabilities	Precarious housing; transient communities	Sex	Water-stressed zones; areas prone to extreme weather events	Political instability	Place-based occupations
Pre-existing mental health conditions	Individuals exposed to abuse/violence	Ethnicity	Conflict zones	Displaced populations; migrants	Migrant workers; informal insecure work
Complex healthcare needs at home	Lack of education, poor literacy; language & cultural vulnerabilities	Indigenous status	Declining urban cities	Discriminated or socially-isolated groups	Self-employed

Figure 2: Factors influencing vulnerability and resilience to flooding.

6 Why should we care about this in Scotland?

In Scotland certain groups – children, older people, those living alone, with pre-existing chronic illness or disability and stressful life circumstances, place-based occupations, low incomes, rural and remote areas – are all more vulnerable to flooding and to extremes of heat and cold.

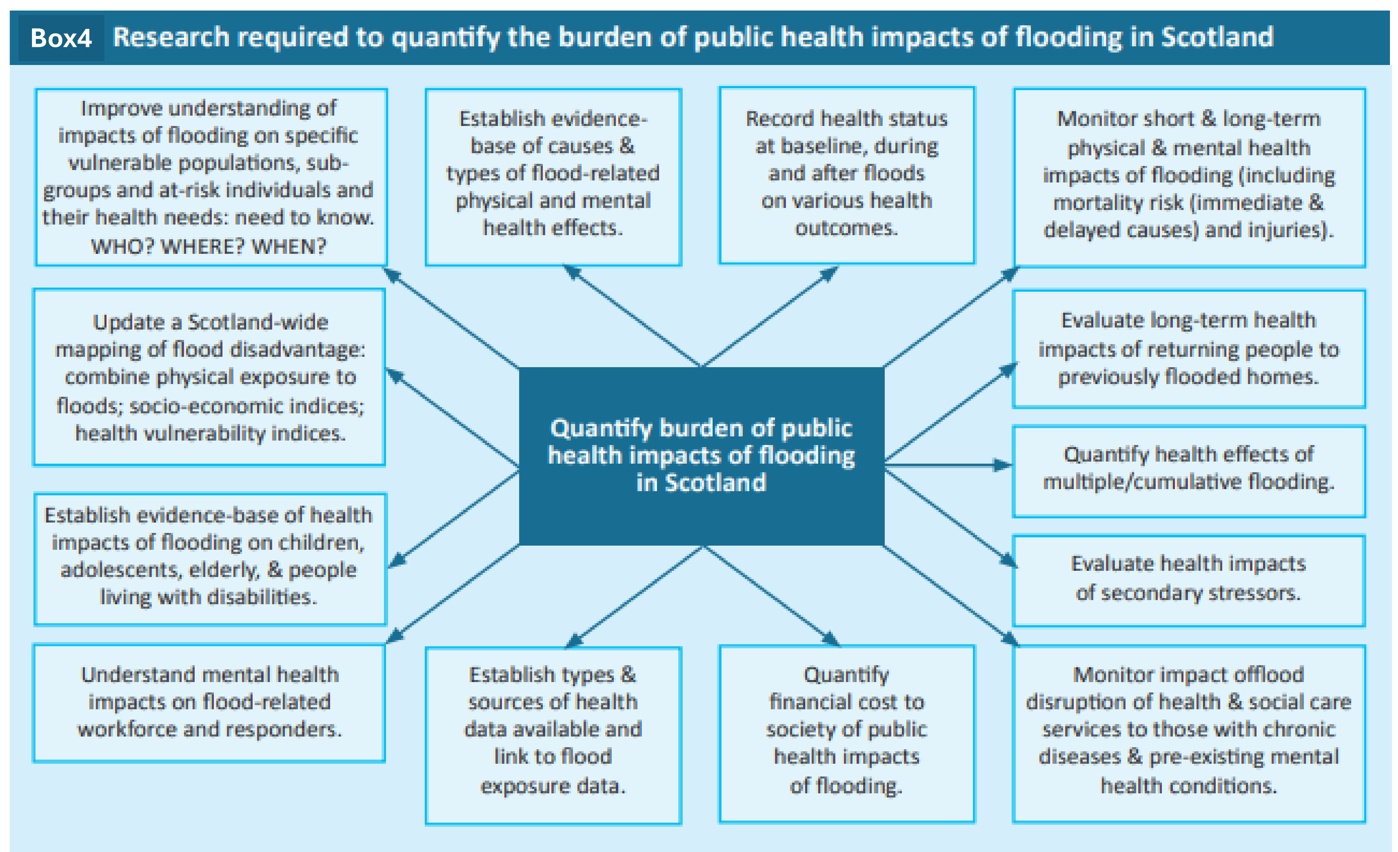
Particular public health-related challenges exist for Scotland and certain factors make Scotland's population more vulnerable to the health impacts of climate change and flooding than other parts of the UK and Europe:

- Scotland's population is ageing; the proportion of the population of pensionable age is expected to increase from about 20% to 25% by 2033.
- Scotland also has areas of greater deprivation and the lowest life expectancy than the rest of the UK.
- Health is poorest in the most deprived areas, with a difference in life expectancy of 13.7 years between men living in the most and least deprived areas of Scotland.
- 98% of Scotland's landmass is classed as rural with a dispersed and ageing population.

Box3 Secondary Stressors

- Lack of warning, not enough time to respond
- Greater flood water depth and duration
- Extent of flood damage
- Structural damage, costs of rebuilding or repair
- Upheaval, financial implications of clean-up
- Distress and financial implications of displacement or evacuation from home (temporary or permanent)
- Loss of domestic utilities
- Loss of/damage to possessions, sentimental items and burden on household costs
- Insurance-related issues e.g. dealing with insurance claims
- Disrupted access: employment, education, and wider facilities, health & social care services
- Separation from friends and family
- Feelings of loss of control and fear of recurrence of another extreme event
- Stress arising from exposure to media
- Damage to agriculture or livestock, leading to loss of food supplies

Box4 Research required to quantify the burden of public health impacts of flooding in Scotland



Box5 Research required on the effectiveness of public health interventions for flooding

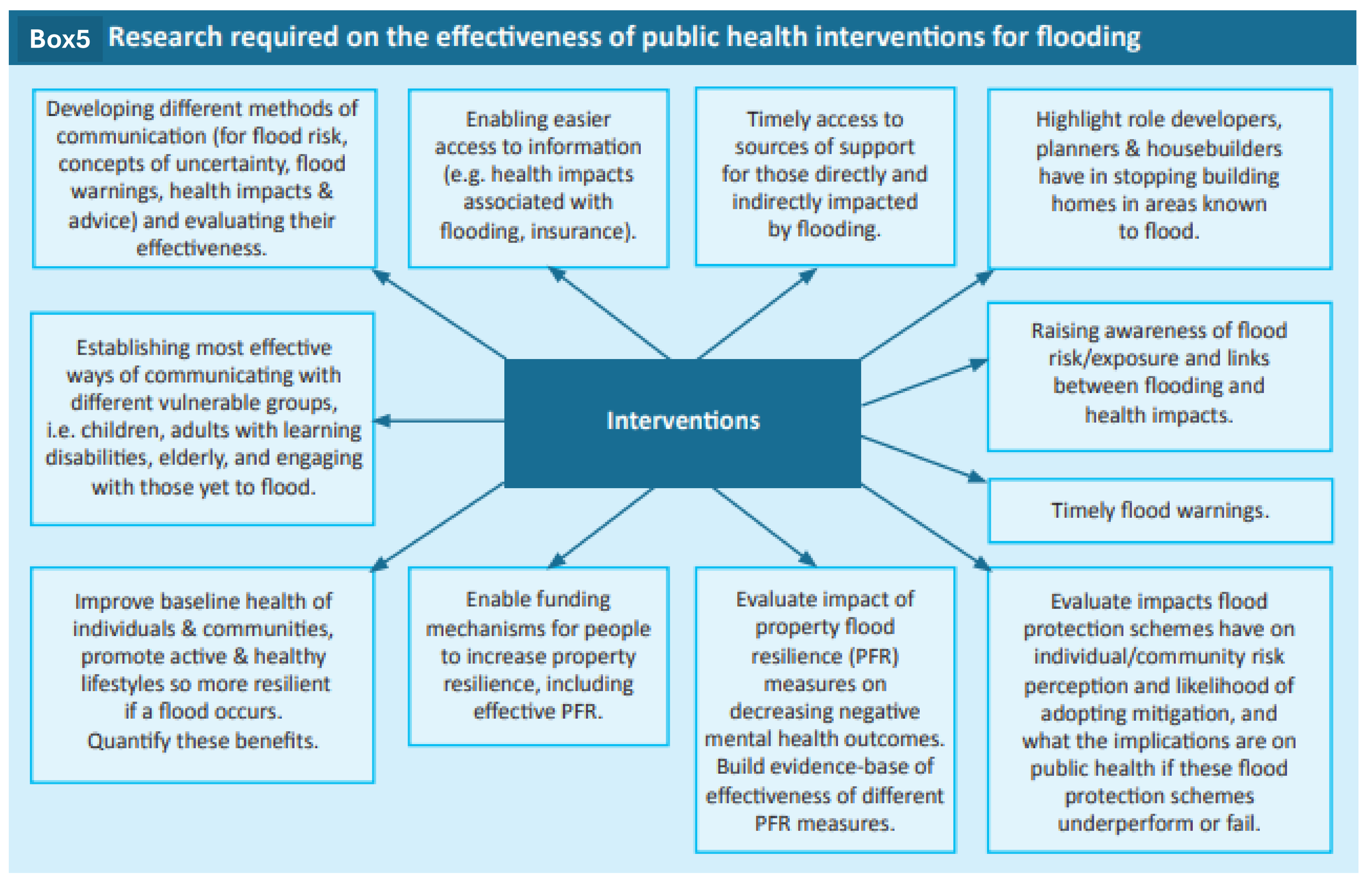


Figure 3: Stakeholder Workshop February 2024

7 What can Scotland do? - Key Findings of Policy Reviews:

- Useful Flood Risk Management strategies exist however most do not incorporate a public health perspective and have not been co-produced with public health experts
- Need to focus on health resilience measures alongside existing resilience measures
- Need to raise awareness of public health impacts of flooding
- Incorporate pre-existing vulnerabilities of individuals/communities in risk/resilience assessments
- Public health policies recognise flooding has a significant impact on health, particularly mental health, and on disadvantaged groups
- Need for further evidence and guidance for vulnerable groups (e.g. children, disabilities)
- Need for research on effective interventions

Findings from the REA of existing literature and policies, along with outputs from a stakeholder workshop (Figures 3 & 4) held with representatives from Scottish Government, Public Health Scotland, regulatory & industry delivery partners, wider stakeholder & knowledge brokers and academia, were synthesised to identify further research required to **a) quantify the burden of public health impacts of flooding in Scotland (Box 4) and b) on the effectiveness of public health interventions for flooding (Box 5). Finally, a set of recommendations was produced (Figure 5).**

Figure 5: Recommendations

Recommendations

To enhance the overall resilience of communities:

- Establish a cross-sectoral flood and public health resilience working group.
- Incorporate a public health perspective within flood risk management plans, focus on health resilience alongside existing environmental, economic & property resilience.
- Increase awareness of public health impacts of fluvial flooding and factors that influence people's resilience through communications and engagement, tailored to different vulnerable groups.
- Promote measures to protect and ensure continuity of public health services and health & social care facilities during floods.
- Greater emphasis on preparedness measures and establishing long-term community-based support networks to assist with secondary stressors and increase capacity to respond.

Figure 4: Visual minutes from stakeholder workshop Feb 2024. Graphic artist: Jenny Capon

8 What Next?

ESRC-SGSSS-funded Interdisciplinary Steers PhD with Prof Hester Parr, School of Geographical & Earth Sciences, University of Glasgow

'Rain rain go away … come back another day': **Understanding Scotland's changing relationships between climate change and mental health.**

PhD candidate: Rhiannon Hawkins start date: Oct 2024.

References:

Thomas, R. and Niedzwiedz, C. (2024) *Building Public Health Resilience to Fluvial Flooding in Scotland Policy Brief*. CSPF2023_01. Centre of Expertise for Waters (CREW). https://www.crew.ac.uk/publication/building-public-health-resilience

Acknowledgements: CREW for funding Science Policy Fellowship.

Modelling Bluetongue (BTV-3) spread and control for Scotland

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Centre of Expertise on Animal Disease Outbreaks

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Introduction

- Bluetongue virus BTV-3 is a non-contagious, viral disease that affects cattle, sheep, goats, deer, and camelids and is primarily transmitted by midges. Bluetongue does not present a risk to human health, but it is a notifiable disease in the UK and can have a devastating impacts on livestock.
- Increased incidence of midges carrying the BTV-3 virus from continental Europe have led to incursions into the East and South of England and disease risk is likely to increase with warmer temperatures due to climate change. There is now evidence of some local transmission of BTV-3 circulating in counties on the East Coast of England (Norfolk, Suffolk).
- The Scottish Government's Centre of Expertise in Animal Disease Outbreaks (EPIC) conducts simulation modelling, movement analysis and economic modelling to evaluate impacts and control options for BTV-3, to support Scottish Government decision-making to assess and minimise impacts on Scotland.

Methods

(1) Snap-out zones (movement analysis):

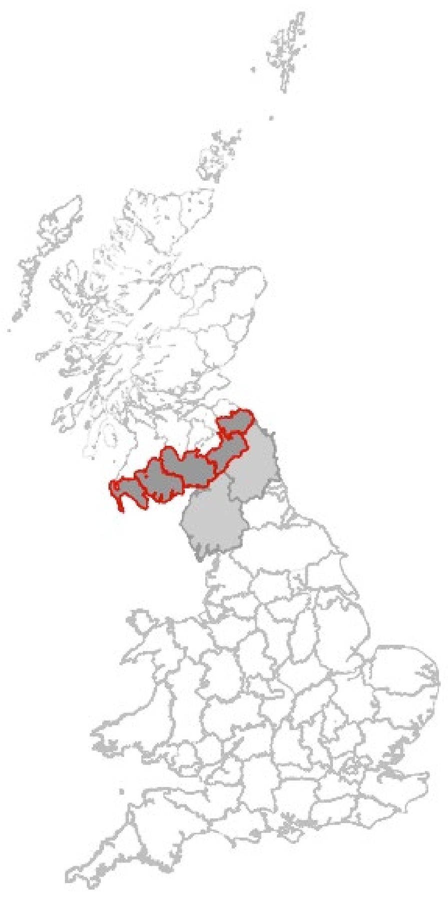
What are Snap-out zones?

- Movements within the zones are permitted.
- Movements from inside to outside zones are banned.
- On incursion of BTV to England, consideration given to snapping out control zones to the whole of England.

Question: What is the predicted impact on movements and trade for Scottish livestock under the following snap-out zone scenarios?

(1) Baseline scenario – boundary is at the English/Scottish border: Scotland is outside any snap-out zones, and the whole of England and Wales are in the zones.
(2) South of Scotland is part of the snap-out control zones.
(3) North of England (along with Scotland) is outside the snap-out zones.

Data: Cattle and sheep movements in GB (2018 – 2023)



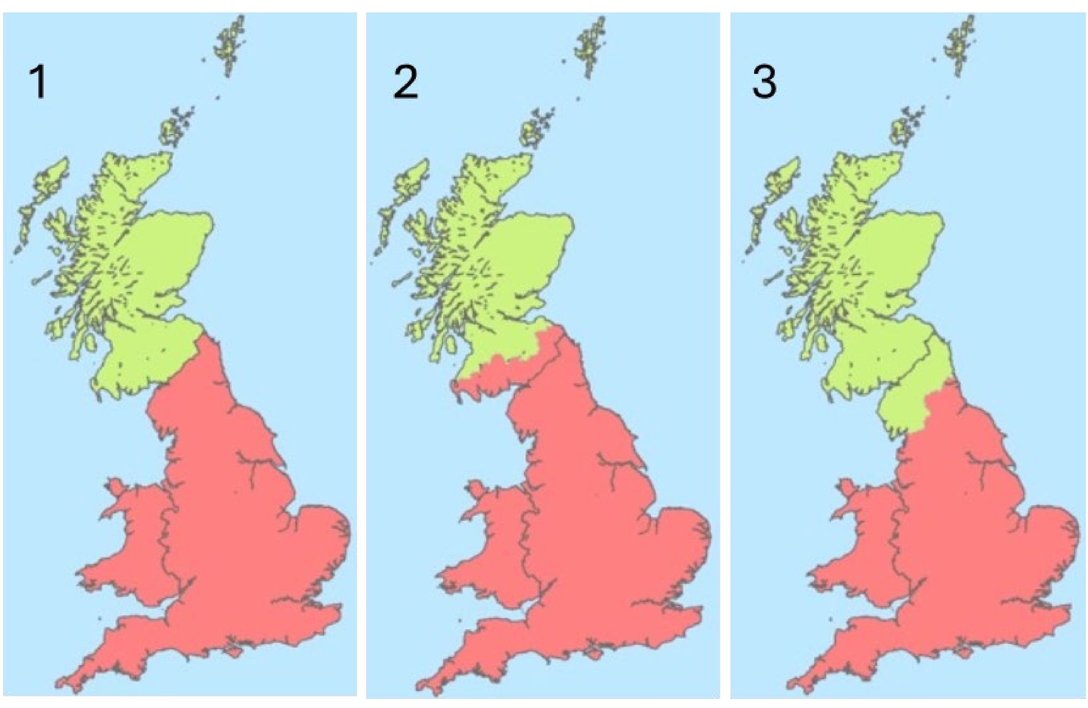


Fig. 1. The 3 snap-out zone scenarios. Animals can move from the green to the red areas, but not from red to green.

(2) Simulation Modelling:

Stochastic model:

Modelling the spread and control of bluetongue virus in Scotland (based on Bessell et al. 2016).

- Simulates between farm spread of BTV; parameterized to BTV-8.
- Generates dynamics of numbers of infected hosts and vectors.
- Between farm transmission based on choice of spatial kernels.
- Extrinsic virus incubation period dependent on mean monthly farm temperatures.

Modelling Scenarios:

- Btv-3 introduction into East Coast of England / Southern Counties of Scotland / Northern Counties of England using HadUK historical 5km-gridded temperature data.
- Evaluate changes if mean temperatures increase by 1°C.
- Ongoing work on vaccination scenarios.

Results

Snap-out zones analyses:

- Including the Southern Scotland (Scenario 2) is most detrimental to Scottish livestock movements: cattle more affected (~9% drop in cattle movements compared to Scenario 1).
- For sheep, the impacts of Scenario 2 are less detrimental, -> ~95% of Scottish sheep can be moved.
- Excluding the Northern counties of England (Scenario 3) allows most Scottish livestock to be moved (99% of sheep , 98% of cattle) but improvements on Scenario 1 are small (~2% increase of movements).

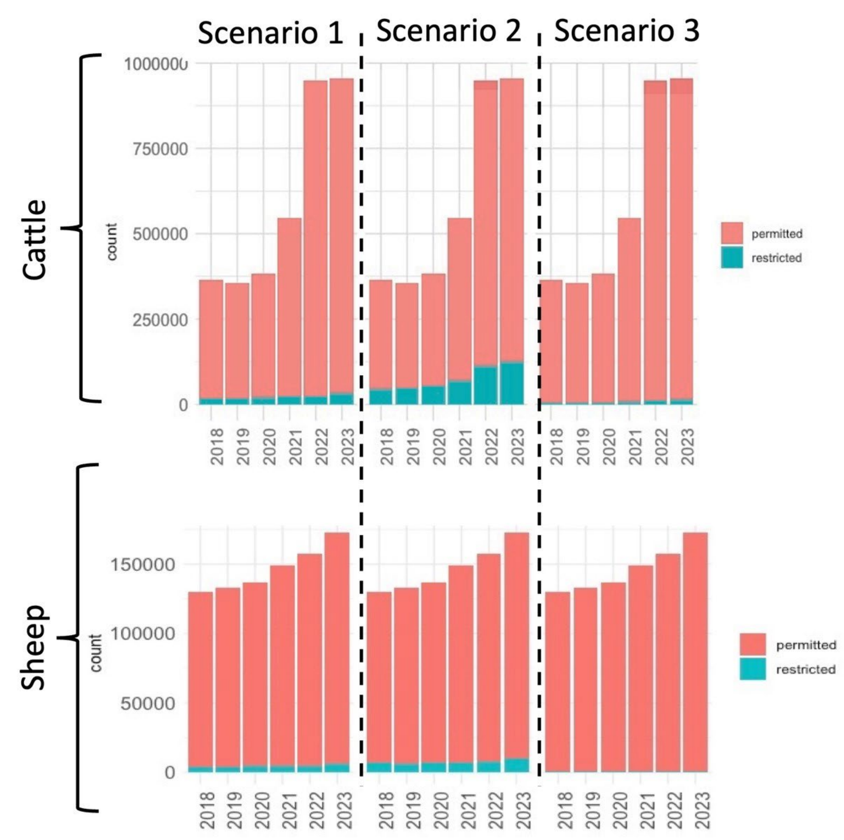


Fig. 2: No. restricted (green) vs. permitted (red) moved livestock for each snap-out zone scenario for cattle (top) and sheep (bottom), as applied to 2018-2023 movement patterns. Scenario 1: England/Wales only snap-out zone; Scenario 2: Southern Scotland in snap-out zone; Scenario 3: Northern England excluded from snap-out zone.

Simulation analyses:

- Incursions seeded into the East Coast of England are predicted to have minimal impact on Scotland.
- There is predicted to be some risk of onwards transmission when seeding in Southern Scotland or Northern England but only minor outbreaks are predicted for Scotland.
- Increased temperatures are predicted to cause larger outbreaks.

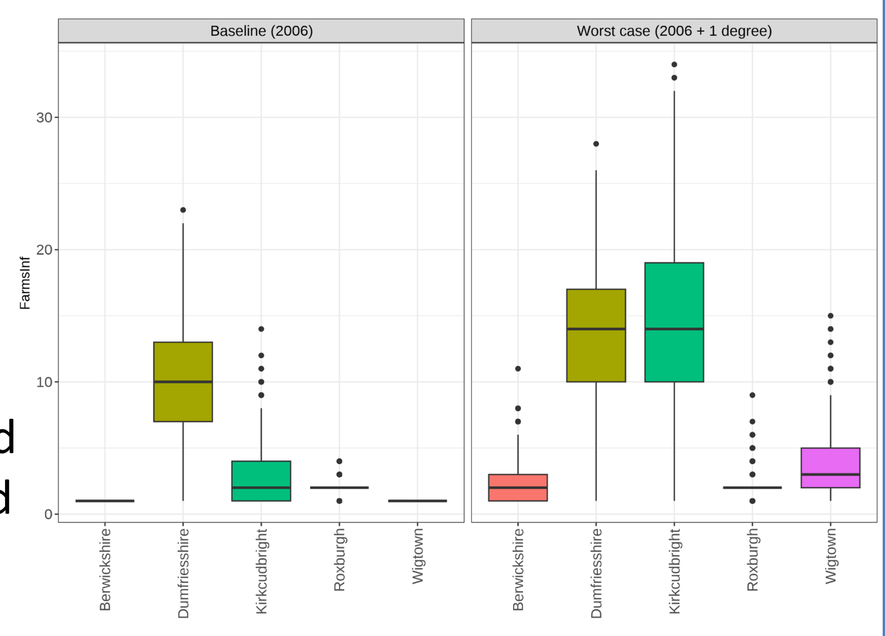


Figure 3: No. of farms in each county of southern Scotland predicted to be infected when BTV is seeded in Southern Scotland under recent climate scenario (left) and under 1°C climate warming (right).

Discussion

- Simulations predict that any incursion in Scotland would cause only minor BTV-3 outbreaks.
- Higher temperatures lead to larger outbreaks but impacts on Scotland are small; highest risk estimated to be when introduction occurs in June/July.
- Simulation model has been adapted to use daily temperatures (both historical and climate projections); Economic modelling of scenarios under way.

References:

Bessell et al. (2016). Assessing the potential for Bluetongue virus 8 to spread and vaccination strategies in Scotland. Sci Rep. 2016 Dec 13;6:38940. doi: 10.1038/srep38940. PMID: 27958339; PMCID: PMC5154200.

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Fingerprinting Pasture Phenolics

Aspects of Biodiversity, Animal Health, and Agricultural Practices

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Introduction

Methane emissions, antimicrobial resistance, anthelmintic resistance, loss of biodiversity, animal health and well-being; the list of **veterinary** and **agroecological challenges** is long. In human nutrition, **phenolics** have been well known for their potential health-promoting abilities. In recent years they've also gained the attention of the agricultural and veterinary sector due to their **potential** to tackle these challenges (Makkar et al (2007)). For **grazing animals**, phenolics could be easily and cost-effectively accessed through **pasture**.

Aim of Pilot Study:

What phenolics are present in different pasture types?

- Gain a better understanding of the phenolic profile of three distinct mixed swards regarding potential health-promoting compounds.
- Evaluate the impact of seasonal and agricultural practices (fertiliser application) on phenolic concentrations.
- Identify botanical functional groups affecting the phenolic profile.

Methods

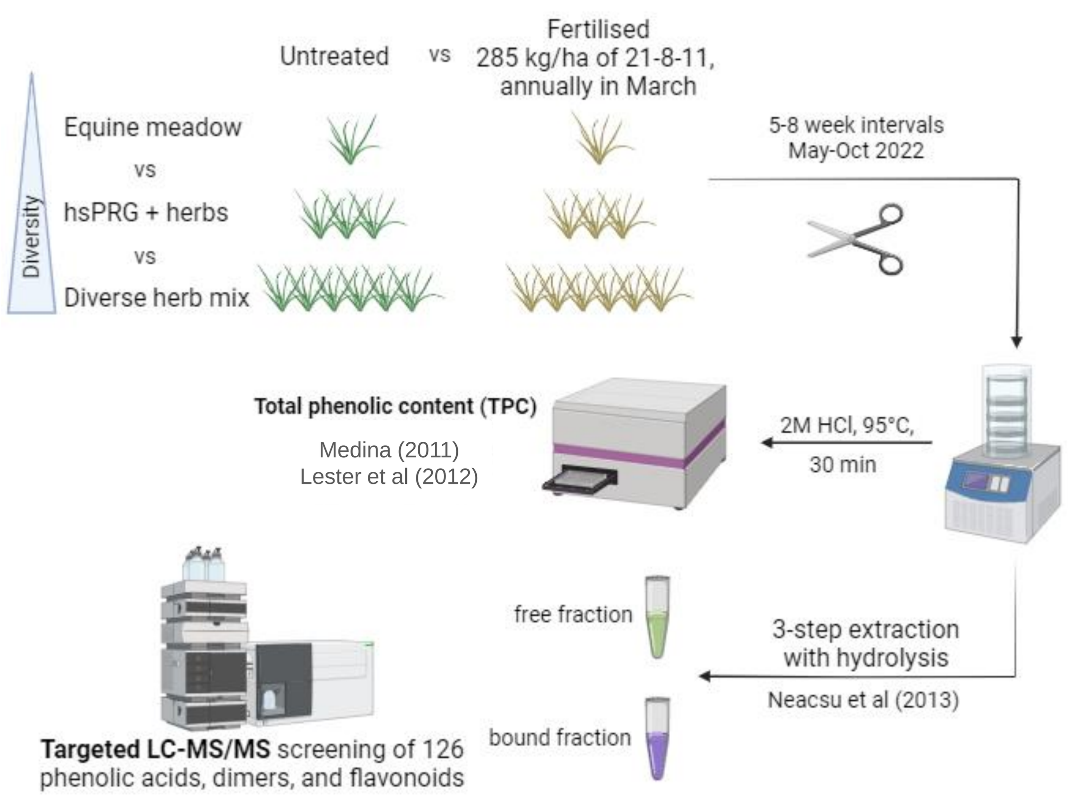

Figure 1. Sample preparation, 3-step phenolic extraction for targeted LC-MS/MS analysis and photometric analysis of total phenolic content (TPC). (created in BioRender)

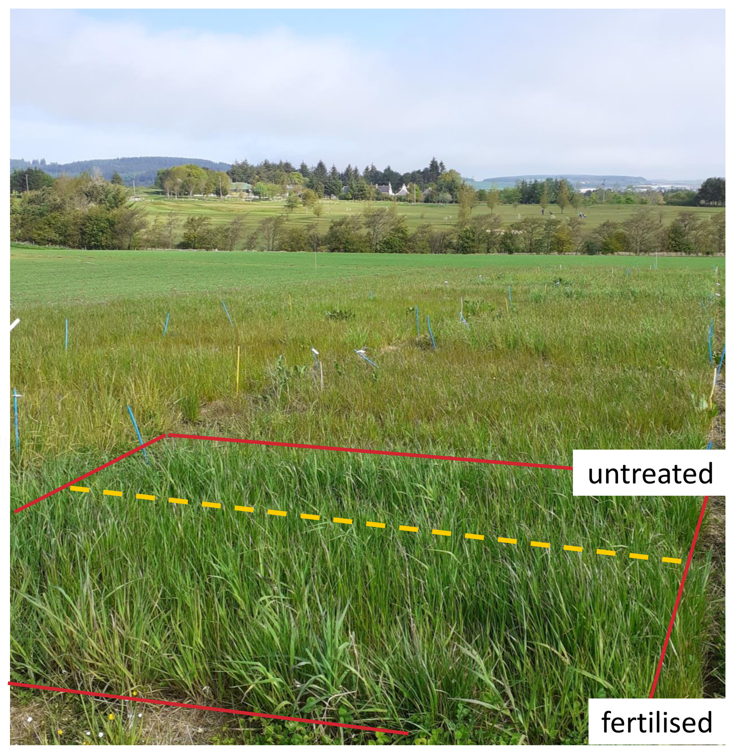

Figure 2. Experimental site at SRUC, Aberdeen (57.180392° N, 2.221272° W) showing fertilised and untreated plots.

Species composition of grasses, legumes, and herbs differed across the three seed mixtures, with diversity lowest in the equine meadow. Biodiversity increased progressively from the high-sugar perennial ryegrass (hsPRG) to the diverse herb mixture.

Results

TPC was highest in the species-rich sward (z=3.55, p=0.006). LC-MS/MS analysis identified chlorogenic acid, ferulic acid, kaempferol, p-coumaric acid, rutin, ethyl ferulate, and quercetin as the most abundant metabolites across the seed-plot mixes.

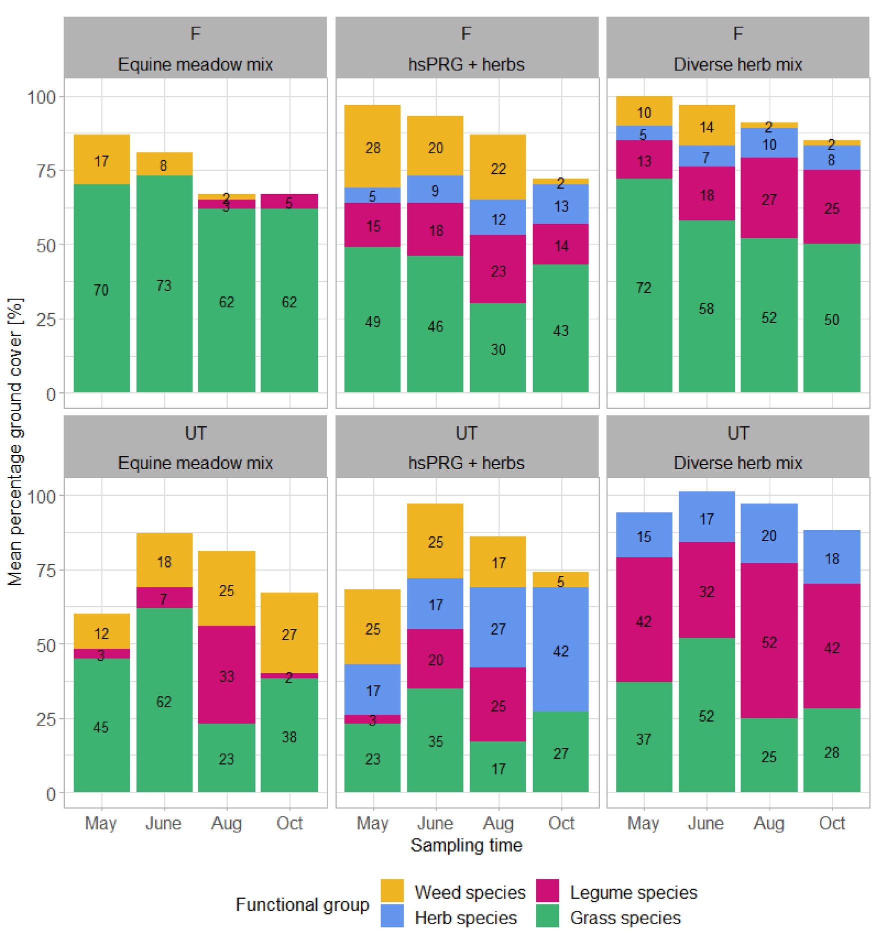

Figure 3. Ground cover estimation of functional groups in fertilised (F) and untreated (UT) plots.

Significant differences in the abundance of functional plant groups were found across the three plots (Figure 3). Species-rich diverse herb mix out-competed weed infestation while equine meadow and hsPRG mix had a higher percentage of weeds and bare ground.

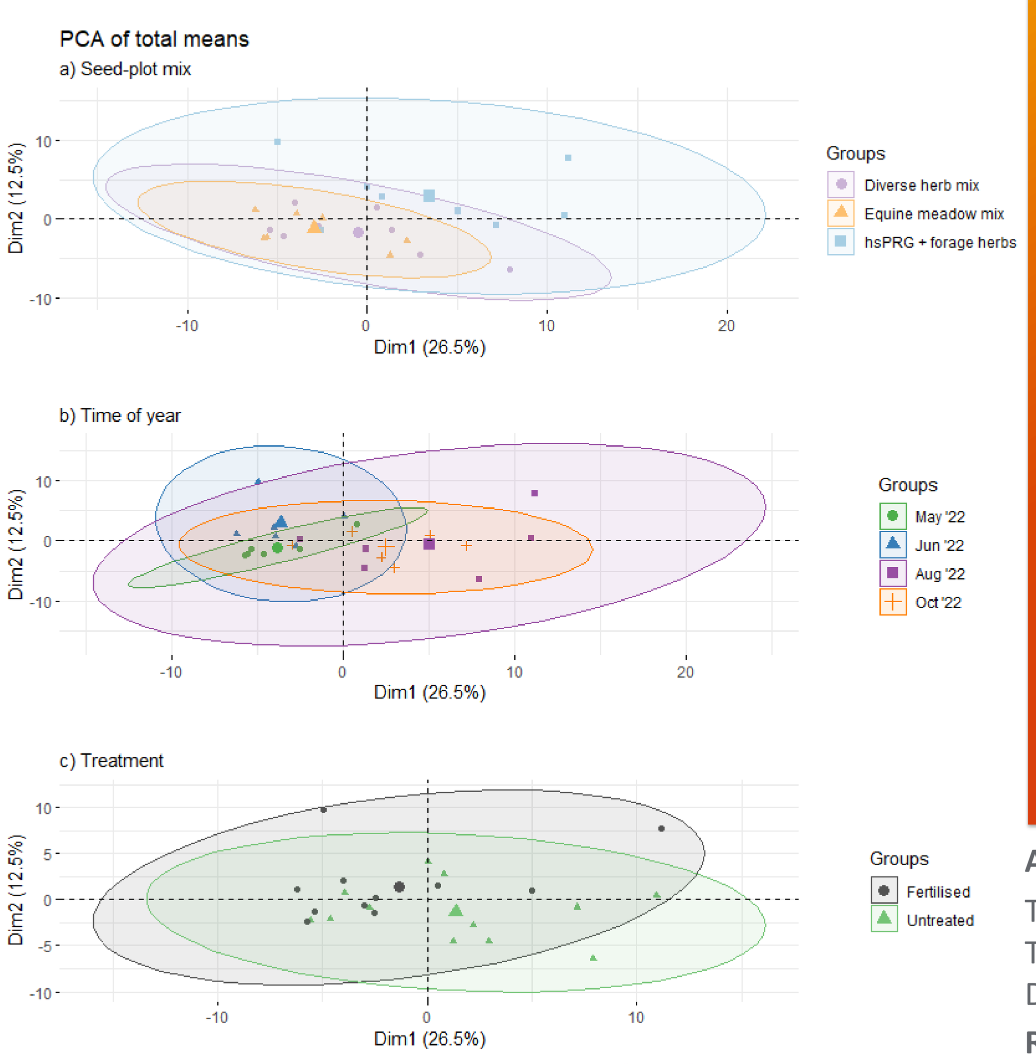

Figure 4. Principal Component Analysis (PCA) of phenolic content (mg/kg DM (dry matter)) measured by LC-MS/MS scaled to unit variance.

The PCA showed: Overlapping clusters of seed-plot mix (Figure 5, a), an increase of molecule diversity in samples collected in August (b), and no differentiation between treatment groups (c).

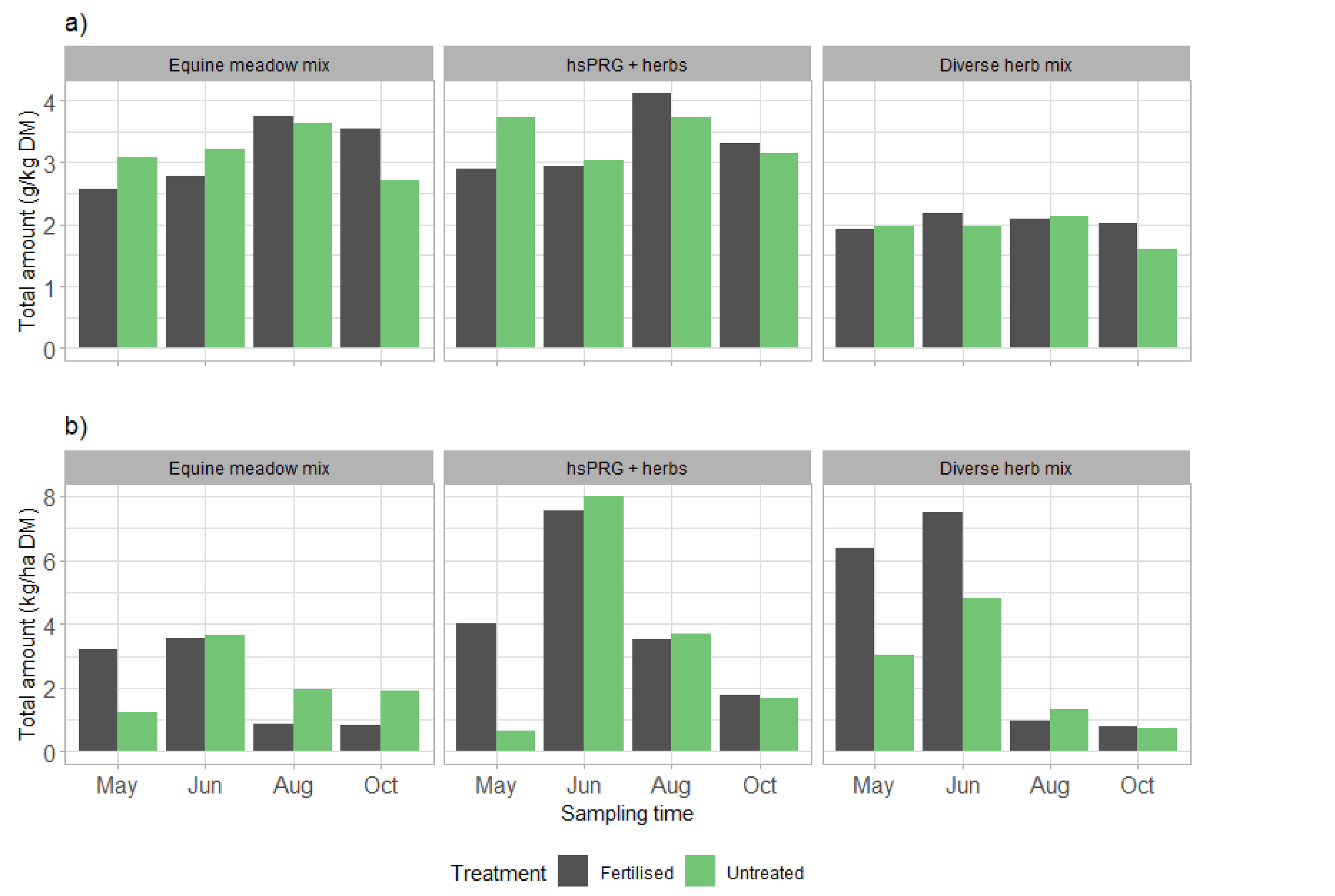

Figure 5. Total amount of targeted phenolics (sum of individual molecules measured by LC-MS/MS) expressed as g/kg DM and kg/ha DM.

The amount of targeted phenolics in the diverse herb mix was significantly lower than the fertilised equine meadow mix (Z= -2.16, p=0.046) as well as the fertilised (Z=-2.55, p=0.032) and untreated hsPRG + herbs mix (Z=-2.65, p=0.024) per g/kg DM (Figure 4, a). The total amount/ha DM in May was significantly affected by the fertiliser application and showed large seasonal variation with increases until June, followed by a decrease across all seed-plot mixes regardless of treatment (b).

Conclusions

First-time application (to our knowledge) of a 3-step hydrolysis extraction to quantify free and bound metabolites in pasture resuted in the successful detection of 101/126 targeted metabolites:

- Whilst **species-poor mixtures** showed **higher total amount** of targeted metabolites per g/kg DM, **species-rich** diverse herb mix had **higher molecule diversity** (LC-MS/MS) and **higher TPC** (spectrophotometric)
- **Seasonal variation** with increased availability (kg/ha DM) in June
- **No effect of fertiliser** application on total amount of targeted phenolics **(g/kg DM)** but **impact total availability (kg/ha DM)** in May only

The pilot study highlights the potential of pasture phenolics in addressing agroecological challenges. Future research should consider plant maturity's influence on metabolite composition, as well as anti-nutrient content and palatability of pastures. An untargeted LC-MS/MS approach should be explored to further investigate the phenolic profile of diverse swards.

Acknowledgement

The work is part of an SRUC PhD studentship funded by the Scottish Funding Council Research Excellence Grant (REG), supported by The Roland Sutton Trust, World Horse Welfare, and Scottish Government's Rural and Environment Science and Analytical Services Division (RESAS) Strategic Research Programme.

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