



SEAMS - Sustainability in Education and Agriculture Using Mixtures

Final Report



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Introduction

What is SEAMS?

SEAMS (Sustainability in Education and Agriculture using Mixtures) is a four-year project funded by the Esmée Fairbairn Foundation, and coordinated by the James Hutton Institute, which ran from April 2019 to March 2023. The project's aims were to develop, promote and implement crop species mixtures as a sustainable crop production system for Scotland and as a resource for knowledge exchange on food production, agricultural ecology and environmental sustainability to a wider audience including school groups.

This report summarises the activities and outcomes of SEAMS. We have kept this report short and "high-level" but have also provided links to more detailed information and outputs related to the various project activities.



What are crop mixtures and why should we be interested in them?

Crop species mixtures – also known as intercrops – involve the growing together of more than one crop species at the same time and in the same area of land. Although a common practice globally, and once common in countries such as Scotland, they have fallen out of favour during the recent drive to highly mechanised and intensive farming. Potential benefits from mixed crops include the maintenance of crop yields with reduced inputs such as herbicides and pesticides, and greater resilience to environmental variability such as summer droughts. Challenges to the wider growing of crop mixtures include the provision of advice to farmers on what to grow and how to grow it as part of a modern farming system, access to specialist machinery (for example seed separation equipment) and generating an understanding of and demand for crop mixture products.

Who has been involved?

The project has been coordinated by the James Hutton Institute and has benefited greatly from the input of a number of organisations which together have constituted our Project Management Group, specifically the Game and Wildlife Conservation Trust, NatureScot, Buglife Scotland, Royal Highland Education Trust, NFU Scotland, LEAF, Soil Association Scotland, and Scottish Agronomy.

On-farm trials of crop mixtures

Overview

A key element of the project was running on-farm crop mixture trials. Our aim was to increase the evidence base available to farmers. We developed a network of field sites across the main arable food production areas of Scotland. These sites trialed crop mixtures, providing information on how to tailor the use of crop mixtures to different locations in Scotland. They also provided a platform for knowledge exchange and learning (see Schools Outreach). The sites were working farms spread across Scotland and the project took a participatory approach, especially with respect to deciding the crop mixtures to be trialed.

We ran a total of 43 trials during the SEAMS project at sites across Scotland (Fig. 1). Generally these were 2- or 3-species mixtures and very often they were cereal + legume (e.g. barley-pea) mixes.

With respect to running the trials an important aspect was providing information to those farmers new to growing crop mixtures on what to grow and how to grow it. **Whatsapp was an invaluable tool** which enabled direct communication between SEAMS farmers and quick support for farmers at key times (for example, when in the field sowing mixtures at the start of the growing season). We were also fortunate in having some **farmers that were very experienced** with growing crop mixtures; in some cases these farmers were invited to join the project because of their contribution to previous sustainable agriculture studies.

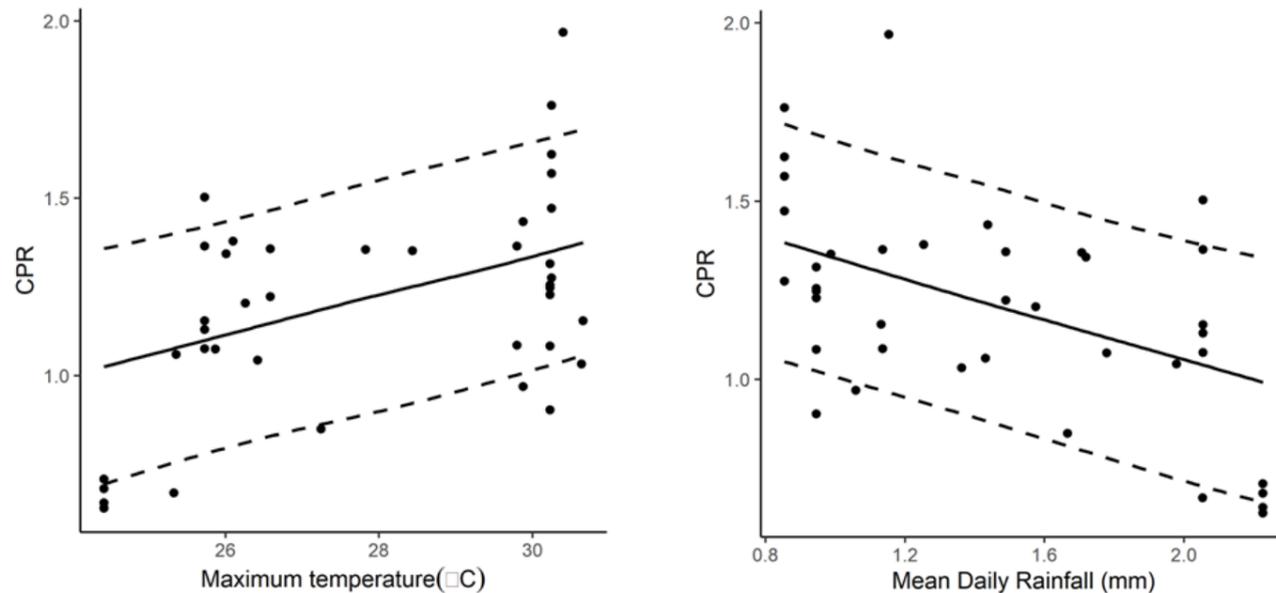
The body of evidence gathered by the SEAMS trials is very substantial and is providing some important initial results which indicate the potential impact of crop mixtures on a range of ecosystem services within crop systems.



Fig. 1 Location of SEAMS trial sites; core sites are shown in orange

Yield

Overall we found a Crop Performance Ratio (CPR) of 1.22 – this means that compared to monocultures of the component crops, **crop mixtures gave just over 20% more yield per unit area**. Other studies of crop mixtures have also found around a 20-30% yield gain. Generally, this was **achieved along with reductions in particular inputs**, for example reduced fertiliser additions when the mixture included a legume. **Nearly all of our trials showed a yield gain relative to monoculture crops**. This is important because it means there is very rarely a yield penalty from growing mixtures.



We found varying effects of crop composition: there was no significant difference in the yield gains from including either pea or beans in the mix, but mixtures with oats and wheat both did better than those with barley. We found no clear effects of management on the CPR. However, we did find **very strong climate effects**, in particular a strong positive effect of absolute maximum temperature and a strong negative effect of daily and growing season rainfall; this means that CPR was highest at warmer and drier sites (Fig. 2).

This is important information as it indicates that, in Scotland, benefits from intercropping might increase as we experience more of the warmer drier conditions expected under climate change. As we might then also expect CPR appears to have been higher in 2023 which was a notably hot and dry year (Fig. 3).

Fig. 2 Crop Performance Ratio (CPR) plotted against growing season maximum temperature and mean daily rainfall

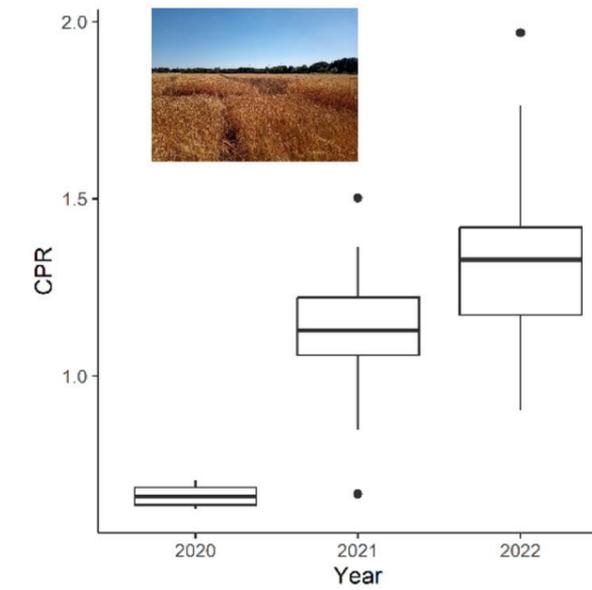


Fig. 3 Average crop Performance Ratio (CPR) for each of the three trial years.

Inset photo shows conditions at our Coaltown of Balgonie site during the hot and dry summer of 2022

Grain and soil chemistry

Cereals appear to have higher N and P levels in mixtures; legume grains have a higher nitrogen (N) content but not phosphorous (P) content; this indicates mixture grains have a higher concentration of nutrients. There were no clear patterns for N or P changes in the soil in response to the presence of mixtures, but mixtures did show reduced soil carbon (C) and loss on ignition (a measure of soil organic matter content). This might be because the more diverse community of roots (and associated root exudates), along with the below-ground activity of legumes, helps stimulate soil processes including decomposition of organic matter. This is an important finding because it has implications for the C balance associated with these crops, but needs further exploration – how much C is lost from the soil? Is it only in upper soil layers? Is this offset by reductions in C emissions from reduced management activity in mixtures?



Soil and bird biodiversity

There were **no clear impacts of mixtures on measures of soil microbial diversity**, for example species richness, although variation in soil biodiversity between farms was very considerable (Fig. 4) and this may reflect factors such as historic management, soil type and climate. It may also be unreasonable to expect a substantial change in soil biodiversity within a single growing season. We have yet to analyse the data for soil nematode diversity.

We did find clear effects of crop mixtures on farmland birds. While the species richness of birds visiting the plots did not differ between mixtures and monocultures, the **number of visits of birds was greater in mixture plots**, and increased with the size of the plot, as opposed to declining with plot size in monocultures. This is an important and novel finding, indicating that species richness may be set by landscape scale factors (for example the range of habitats and availability of nesting sites) but for those species present mixtures are more attractive. This may be because of factors such as enhanced food availability and/or cover in the mixture plots.

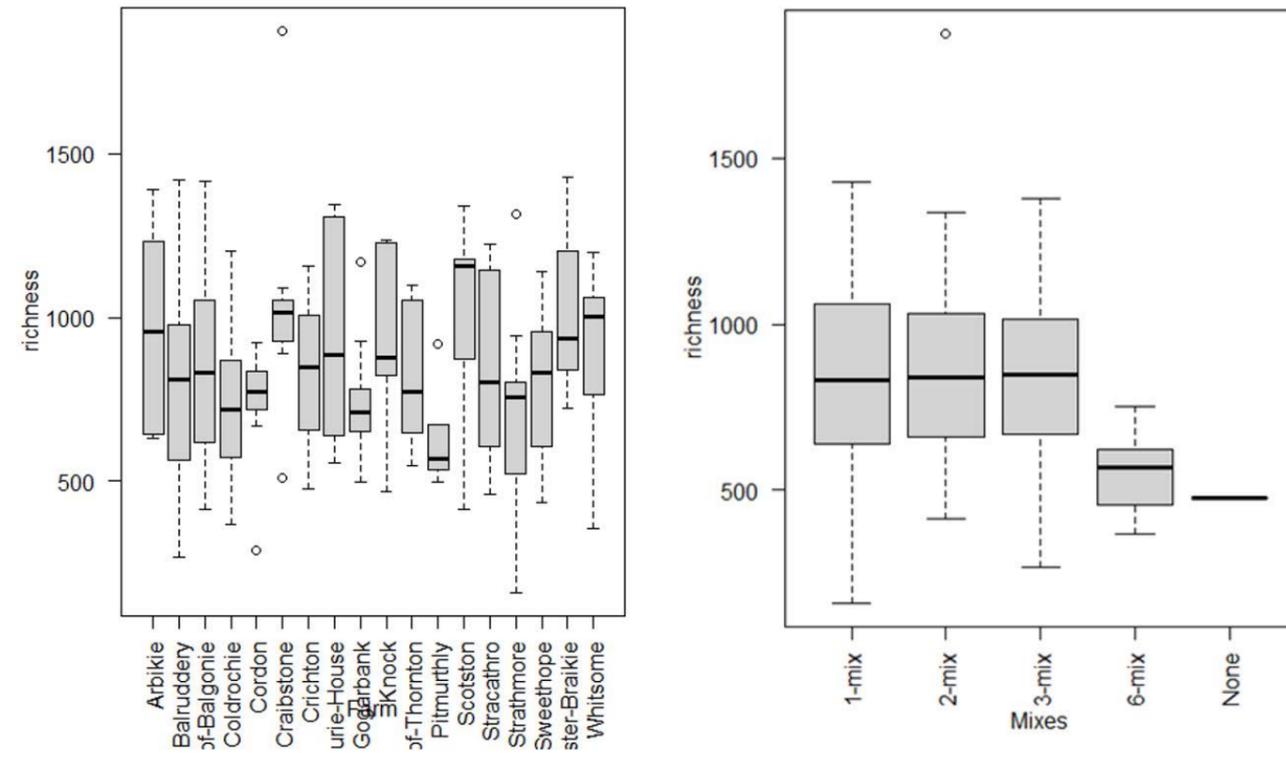


Fig. 4 Richness of the soil microbial community plotted against site and number of components in the species mixture.

Online data platform

A final key element of our trials work was the **development of an online data platform**. This is aimed at providing a simple central location for accessing the data gathered by SEAMS (and other crop mixture trials). We hope this platform will be used by a wide range of stakeholders to see what crop mixtures have been grown where in Scotland, how they've been grown, and what the results were. The platform can be found at <https://ics.hutton.ac.uk/seams/#/>.

Lessons learned and next steps

Lessons learned

- The data gathered have given us new insights, both into the effects of crop mixtures, and into how best to grow crop mixtures in Scotland.
- Funding available to farmers to help offset the cost of crop mixture trials has been an important part of encouraging farmers to run trials.

- We have relied heavily on some experienced farmers to provide information, guidance and support to those new to crop mixtures. Farm visits were very difficult during Covid; even when we did run these attendance was limited in part because trials sites are widely spread and also because farmers are very busy; our SEAMS farmers Whatsapp group – developed in part because of the challenges of working during Covid - has been an invaluable tool for farmers to co-support each other.

Our next steps are:

- Finalise our data analysis and publish the results both in peer reviewed journals and also in formats which are accessible and relevant to farmers and policy makers.
- Continue to develop the online data platform.



Schools Outreach

Overview

Our initial aim was to use the SEAMS trials sites as platforms for outreach with schools. Crop mixtures represent an excellent educational opportunity for engaging school children on topics such as the role of biodiversity in delivering ecosystem services, food production, sustainable farming, and climate change. Our schools outreach work had to be substantially restructured because of the COVID outbreak, moving much of it online or to remote activities. Within this restructured approach we have delivered a number of activities/events.

- **Online resources for pupils/teachers**, including information on the ecology of intercrops, their role in sustainable farming, and online maths resources explaining how crop mixture effects are calculated – more than 1000 visits; Sustainability and crop mixtures learning resource
- **Crop mixture seed packets** as well as information on growing the seed in both monoculture and mixture, and links to our online content, were sent out to schools – 24 school requested seeds for planting.

In 2022 we were also able to run some field visits to 7 farm sites which provided engagement for 200 pupils.

A brief overview video highlighting our school outreach work is available here: <https://youtu.be/laYGO3qs5Rk>

Lessons learned and next steps

Lessons learned

- The provision of online resources was very well received, particularly during a period where the ability of schools to undertake in-person field visits was hugely restricted. The online schools resource now provides an important part of the SEAMS legacy.
- Training in online recording apps such as iRecord could help with farm visits.
- It would be good to follow up in a classroom setting on the data emerging from the farm visits. This might also help to get back data from activities such as the seed packets.
- Teachers struggle to have capacity in the curriculum to undertake visits; we could explore opportunities to work with groups outside of schools to cover a longer growing season.
- Increasing digital engagement with farmers would increase content available for producing learning materials.
- Linking our education work directly to our field trials work is a novel aspect of the project; the effort to engage schools is substantial, but it has added substantial value to the project that the trials have provided the basis for educational activities around the sustainability of food production.

Next steps

- The online crop mixtures resources will continue to be used in the coming year as a focus for school engagement by Royal Highland Education Trust (RHET). Another set of

mixture seed packets is being sent out this spring to schools across Scotland as part of RHET's activities.

- iRecord instructions will be included into activity packs for farm visits (RHET and Buglife Scotland).

Policy, business, and other outreach

Overview

SEAMS has undertaken a wide range of outreach. As well as the work with farmers focussing on our trial sites, we have undertaken outreach activities with policy makers, businesses other than farms, and with other stakeholders.

Policy outreach

Our aims with respect to policy outreach were to raise the profile of crop mixtures as part of the toolkit for delivering sustainable agriculture. Ultimately, we hoped that they would be integrated into options for sustainable farming support from government, as this is a key lever in getting uptake by farmers. Highlights from our policy outreach activity include:

- A farm walk with MSPs at the Hutton Institute's Balruddery farm – August 2019
- A visit to Durie Farm including representatives from Scottish Agronomy, NFU Scotland, SASA and Scottish Government agricultural policy staff – October 2021



- Scottish Government RAINE (Rural Affairs, Islands, and Natural Environment) committee discussions – November 2021
- Royal Highland Show, including discussions about farm mixtures with Ministers and Parliamentarians from both the UK and Scottish Governments – July 2022

Both “Use of N Fixing Crops” and “**Inter-cropping, under-cropping and mixed cropping (e.g. peas and barley) and avoid monoculture**” have been included in a list of potential measures for inclusion in future farm support mechanisms released by Scottish Government (<https://www.ruralpayments.org/topics/agricultural-reform-programme/arp-list-of-measures/>). This list of measures is currently being appraised by Scottish Government. Although it is hard to attribute a direct link between any project and a policy outcome, we hope that we have raised the policy profile of crop mixtures, promoting its inclusion in this list. It was also noted at the SEAMS wrap up meeting that the SEAMS data platform and accompanying datasets are well-placed to provide the evidence base for including such a measure in future support mechanisms.

Lessons learned

- Piggy-backing on activities such as the Hutton’s presence at the Royal Highland Show enabled us to achieve greater policy reach than we might have achieved as a stand-alone project.
- The war in Ukraine focussed attention on food security, not least those routes to food security which enabled a reduced dependency on synthetic fertilisers. This probably delivered more policy interest than general messages around

sustainability and biodiversity loss. In future we should be more pro-active in reframing our message to the likely immediate interests of a policy audience.

- The data provided by field trials is essential in supporting options appraisal; having a strong set of data from Scotland is valuable.

Next steps

- We will continue to provide information to policy makers as the results from our crop mixtures trial sites are finalised, picking up on lessons learned about how best to frame the message.
- We will engage with current discussions being coordinated by Scottish Government on options to include in future farming support mechanisms.



Business outreach

Our aim with respect to outreach to the business sector (away from farm businesses) was to increase the demand for crop mixture products. Having reliable demand for the products of crop mixtures is a major factor in encouraging farmers to grow mixtures.

We undertook two workshops with businesses. Our first one was a generic **buyers workshop** (October 2021); we intended this to be a first step to working with food producers to increase the use of crop mixtures. Key messages from this workshop that influenced our later outreach activity in this area were:

- When crop mixture products are bought for food production they are normally mixed in with grain from conventional production systems. This makes it hard to recognise and promote the sustainability credentials of products from crop mixtures, and also causes concerns about cross-contamination.
- There is no clear certification systems or marque for crop mixtures; this is in contrast to organic certification where the increased cost/complexity of growing organic produce is recognised through increased prices which can be charged ultimately to consumers on the basis of organic certification.

Building on this learning, **our second workshop (Feb 2023) was a small group discussion focussed on the brewing and distilling industries**. Although a departure from our initial aim of promoting crop mixtures for direct human consumption, we decided there were opportunities for encouraging crop mixture uptake in the brewing and distilling sector. Small batch distilling and brewing can handle the small volumes of product

currently supplied from crop mixtures while at the same time promoting the sustainable origin of the raw materials, thereby enabling a return based on sustainability. Small batch brewers and distillers are in some cases also less concerned about raw materials meeting particular quality standards; they are happy to be experimental in their use of raw materials. In addition, brewing and distilling in Scotland accounts for roughly 20% of the barley market, which in turn impacts on a substantial amount of Scottish arable land. There is also a major drive to reduce the sector’s carbon footprint, and so we hoped the potential for reduced C emissions from crop mixtures would be of interest to this sector. Important messages arising from our second workshop were:

- There is work to do raising the profile of crop mixtures as a sustainable farming system which can help support the brewing and distilling industry.
- There was considerable interest in the potential for crop mixtures to be part of the toolkit for sustainability in the brewing and distilling sector.
- Bespoke advice on – for example – suitable variety types would support small-scale brewers and distillers to use products from crop mixtures.
- Scaling up represents a challenge for integrating crop mixture products into the mainstream brewing and distilling sector. Future farm support payments will be key in encouraging growing of crop mixtures at scale.

Lessons learned

- Discussion with food producers and brewers and distillers identified some key challenges for promoting the use of crop mixtures products that we would otherwise have been unaware of, for example the lack of a dedicated sustainability marque.
- Focussing on particular sectors – for example brewing and distilling – provides a good opportunity to understand thoroughly the barriers and opportunities that exist for that sector, including for businesses of different size; this in turn enables us to better tailor the information we provide about crop mixtures, for example focussing on potential carbon emission benefits.

Next steps

- We will be promoting results from the SEAMS project through events orientated to the brewing and distilling industry; we feel there is a genuine opportunity here to develop demand for the products of crop mixtures at scale. Events include the International Barley Hub seminar series (April 2023), and the World Distilled Spirits Conference (May 2023).
- We need to do more full life-cycle analyses comparing crop mixtures and monoculture cropping. We expect the reduced inputs associated with crop mixtures will mean their GHG emissions footprint will be lower than that of conventional monoculture crops. However, we have few detailed analyses of this kind, and need this evidence to present to buyers.



Other outreach

In order to deliver against our project aims, we have focussed particular elements of our outreach activity on specific groups of stakeholders (farmers, schools, policy makers, food/drink producers). However, we have taken other opportunities as they have arisen to promote the SEAMS project and the potential of crop mixtures to deliver sustainable farming. This wider outreach activity has included:

- Over 30 blogs, articles and webinars
- Over 15 conference presentations
- Podcasts

As for elements of our policy outreach, some of these opportunities have arisen because we have piggy-backed on to other events/activities. For example the SEAMS project was mentioned at the 2020 World Biodiversity Forum in Davos as part of a more general discussion on crop mixtures and sustainable farming. Full details of our outreach activity was provided as part of the SEAMS annual reporting.

Lessons learned

- Our Project Management Group has been central to identifying opportunities for promoting the project and its results, for example through newsletters, podcasts, webinars. It has been of huge benefit to the project to have a varied Project Management Group working across multiple stakeholder sectors.

- We all learned a huge amount about online communication routes because of the pandemic; these activities have enabled us to have an international reach, with attendees at events from New Zealand and Canada, something we didn't envisage at the start of the project.

Next steps

- We have a highly valuable pool of materials and resources. This will be curated and catalogued at the end of the project to provide a resource that can be easily drawn on for future outreach activities.



Delivery against key outcomes and project summary

SEAMS has three key outcomes linked to our major areas of project activity.

First key outcome: *Increased incidence of crop species mixture farming in Scotland. Increased awareness of the methodology.*

We have delivered against this Outcome in a number of ways. Directly, the project has funded farmers to undertake crop mixtures trials on their farms. The delivery of these trials has been helped by the use of social media enabling farmers to share information on how to grow crop mixtures.

We have also delivered against this outcome indirectly by:

- Setting up our online data sharing platform to provide interested farmers with information on what crop mixtures might work well for them, and how to grow them.
- Promoting the use of crop mixtures as part of the sustainable farming toolkit in discussions with policy makers; changes to farm payments which support crop mixtures could further increase the amount of land being farmed as crop mixtures in Scotland.
- Raising the profile of the products of crop mixtures with food and drink producers. This has highlighted for us opportunities to explore how crop mixture products can be a larger part of

a sustainable food supply chain, which in turn will increase demand for these products.

Second key outcome: *Soil health improved in crop species mixtures plots relative to monoculture plots.*

It would be fair to say that when we set this key outcome our approach was overly simplistic. The issue of soil health is a very hot topic, a key challenge being to define what a healthy soil looks like. What metric can we use to define a healthy soil, and would the values for that metric be the same for different soils in different locations and under different management regimes?

In the SEAMS trials, while our initial analyses have not identified substantial changes in microbial biodiversity, we have seen increases plant nutrient concentrations (potentially through increased plant-available nutrients in the soil) and reduced soil carbon (C) and loss on ignition in mixture plots. These responses point towards increased soil function in terms of decomposition, which would release nutrients and reduce soil organic matter; increased soil function can be interpreted as a metric of soil health.

It is important to consider though whether the reduction in soil carbon is a cause for concern. Further analysis is needed to put soil carbon measures within the wider framework of soil health, and to also assess the balance between reduced soil carbon and reduced carbon emissions achieved elsewhere through growing crop mixtures (e.g. through reduced inputs and management). Importantly SEAMS has developed a substantial dataset from



which to further explore these questions, and to link our findings to work currently underway on soil health, for example the Healthy Soils component of the current Scottish Government Strategic Research Programme¹.

Third key outcome: *Policy/decision maker engagement with CSM agriculture.*

As noted under “Policy, Business and Other Outreach” the SEAMS project has been actively engaged in organising a range of opportunities and activities for discussing crop mixtures with policy makers from both the Scottish and UK Governments. We feel that small group or 1:1 discussions have been particularly important in these communication activities.

We are particularly pleased to see the inclusion by the Scottish Government of crop mixtures as a potential measure for future farm support. This can only help to further raise the profile of crop mixtures to policy makers. A key opportunity now is to feed results from the SEAMS project into this decision-making process.

Overall, we feel we have delivered against our initial aims to develop, promote, and implement crop species mixtures as a sustainable crop production system for Scotland and as a resource for knowledge exchange on food production, agricultural ecology, and environmental sustainability to a wider audience including school groups.

Fundamental knowledge from on-farm trials and discussions with our participating farmers has given us the information and credibility we need to talk about crop mixtures to policy makers, food producers, and the public. We have also been able to support learning on a wide range of issues by school children across Scotland.

There is a genuine opportunity now for crop mixtures to be an important part of future farming systems in Scotland. On the policy side crop mixtures are a potential part of the future farm support payments scheme, but evidence is needed for this to progress. On the food/drink production side, some sectors with significant influence on Scottish farming – for example the brewing and distilling industry – are looking for new options to make their supply chains more sustainable.

The new data acquired by the SEAMS project, as well as the new working relationships we have fostered, puts us in an ideal place to continue to promote crop mixtures to policy makers and buyers, helping provide policy support to farmers and a demand for mixture products. We also have a wealth of information - which we are making openly available on our data platform – which can support farmers interested in growing crop mixtures to decide what to grow and how to grow it. Overall, this is a direction of travel which we hope will lead to the widespread growing of a more sustainable crop production system.

And finally...

We would like to end this report by thanking all of the people that have contributed to the SEAMS project, not least our participating farmers. We also gratefully acknowledge the funding and support of the Esmée Fairbairn Foundation.

SEAMS Project Partners



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For more information on the SEAMS project:

Visit <https://www.hutton.ac.uk/research/projects/seams-sustainability-education-and-agriculture-using-mixtures>

Or contact Rob.Brooker@hutton.ac.uk

¹ <https://www.gov.scot/publications/environment-agriculture-and-food-strategic-research-2022-27-overview/pages/strategic-research-programme-2022-to-2027/#researchprogramme2022to2027>

