

The adoption of agroecological principles in Scottish farming and their contribution towards agricultural sustainability and resilience

SEFARI fellowship project report
by
Luz Maria Lozada & Alison Karley
The James Hutton Institute, UK

In collaboration with:
Sue Pritchard, Genevieve Agaba, Tom Burston, Allison Caffyn & Lucianne Wardle (Food
Farming and Countryside Commission)
Mat Roberts (Independent Sustainability Advisor)
Jim Booth (Scottish Agricultural Organisation Society)
Aoife Behan (Soil Association)
Lorna Dawson (SEFARI Gateway)

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Key messages and recommendations

Policy and governance

- Farmers and crofters are motivated to practice agroecological principles (as defined by the UN's Food and Agriculture Organisation) for sustainability and resilience in response to climate change and the perceived need for food system change.
- Agroecological approaches provide a broad pathway to sustainability in agriculture and are being practiced by many Scottish farmers and crofters, largely without financial subsidies.
- Agroecological approaches are knowledge intensive, therefore widespread availability of training and advice could support future agricultural transitions, taking account of different ways that new information is acquired. New entrants have a higher propensity to adopt agroecological principles and gender can affect which methods of new knowledge acquisition (and co-creation) are preferred.
- Enabling agroecological practices and principles to flourish has the potential to deliver policy ambitions for biodiversity gain, carbon sequestration, healthy food production and a just transition. Farm support schemes could be aligned to encourage a range of foundational practices across whole farm units and incentivise rapid investment in agroecological farming systems that deliver nature-based solutions for sustainable farming and food production. Other support could include building on farmer-led groups to develop new skills and encourage new entrants, and using public procurement to generate consumer demand for sustainably farmed products.

Farming practices

- Farmers and crofters are already practicing the ten elements of agroecology as defined by the UN's FAO (some of them as an intentionally planned holistic system and as an alternative agricultural and food production paradigm).
- Farmers and crofters use different sources of information as part of the co-creation of knowledge (experimentation, advisory services, directly from other farmers/crofters).
- Agroecological approaches demand better understanding of ecological processes and integrate the farming operation with the local community and food system. Ways of measuring the economic and social benefits, as well as environmental and agronomic benefits, (and disbenefits) are needed to evidence improvements made to farming systems.

Future research

- More detailed analysis is needed to quantify the proportion of farmers and farmed land where agroecological approaches are applied in Scotland to understand where most benefits can be gained and where support should be targeted.
- Farming support mechanisms would benefit from better understanding of the effects of gender, age and other social factors on the adoption of knowledge-based farming innovations.
- Accounting studies of the social, economic and environmental performance of agroecology farming systems compared with conventional farming systems and between different farm scales would allow stakeholders to make informed decisions. This would allow the viability of these two farming approaches to be tested when financial subsidies are deducted (including social, economic and environmental viability).
- Based on the above analyses, appropriate metrics of social, economic and environmental performance of alternative farming approaches could be devised for use by farmers/crofters and policy (e.g. in implementing agroecology support mechanisms).

Executive summary

- **Can ‘agroecological’ farming approaches improve the sustainability of agricultural businesses in Scotland and their resilience to external shocks?** An online survey and one-to-one in-depth interviews were conducted with volunteers to understand how agroecological practices are applied in Scotland to improve agricultural sustainability and whether these deliver beneficial outcomes, and to understand the perception of farmers and land managers about agroecology as an alternative paradigm for agriculture and food systems.
- **Survey respondents** encompassed the range of farming enterprise types in Scotland and reflected the composition of agricultural community in some characteristics (land tenure, age structure, gender) but not others (11% were organic farms). Out of 192 online responses, more than half (60%) farmed using an approach that could be classed as agroecological. **Interviewees** for the agroecology case studies were implementing agroecological principles and were mostly female (seven out of ten). Interviews captured all enterprise types except dairy farms and intensive cash/combinable crops.
- **Agroecological characteristics** most observed in Scotland included practices of **recycling and efficient use of natural resources** (by managing soil tillage, soil nutrient inputs, and drainage). Practices underpinning **diversity** were moderately common among survey respondents and used frequently by interviewees. Evidence was more variable of practices being used to promote **resilience** to pests and diseases and **synergies**, which mostly related to integrating livestock, foraging and soil health. This might suggest constraints on the use of certain agroecological practices in Scotland.
- More than two-thirds of respondents obtained new information at least partially through their own research and experimentation and a significant proportion of respondents consulted others, indicating widespread use of the agroecological principles of **co-creation and sharing of knowledge**. Amongst survey respondents, males were more likely to use paid advisory services than females. Interviewees obtained their information mainly through their own research and all of them were in a continuous process of learning. This emphasised the importance of peer learning.
- **Social and cultural context of agroecology in Scotland.** New farming entrants (29% of respondents) featured more strongly in adopting agroecological farming approaches. The primary motivations for implementing agroecological farming practices were to improve soil health and biodiversity and reduce inputs; those practicing agroecological approaches were more likely to indicate success in achieving these outcomes. Although agroecological practices were felt to improve farm resilience, few linked this to improved financial strength, indicating a knowledge gap about the role of agroecology in **improving rural livelihoods** through social and economic outcomes (as well as environmental outcomes). Interviewees on the other hand recognised the benefit of their agroecological practices on their own community and they saw themselves as agents of change and having more autonomy to create alternative food production systems. Survey respondents and interviewees supported **cultural values around diet and food consumption** by strengthening connections between food production and local or traditional food habits.
- **Enabling environment for agroecological systems in Scotland.** Many survey respondents were supportive of sustainable farming approaches to minimise the environmental impact and carbon footprint of agriculture. Interviewees mentioned access to land as a barrier to

new farming systems. Within agroecology's principles access to land is an essential part of responsible governance.

- Even though most of the respondents (60%) were practicing agroecology or an alternative farming system, half of them had never participated in any environmental incentive scheme. This could indicate that farmers and crofters who are implementing these practices might be willing to absorb the cost of implementing agroecology and/or that farming practices supporting a transition to agroecology as a food system paradigm do not lend themselves to existing support mechanisms. Most of the interviewees are shortening the food chain by connecting directly with consumers. Some of them do so at a premium price and others go as far as to sell for affordable prices to increase demand for nutritious food in their local communities. The findings indicated that agroecological goals of **responsible governance** and **circular and solidarity economy** are at an early stage of development in Scottish farming but could develop in response to upcoming legislation around farming and food production.
- **Understanding of agroecology** as an approach or paradigm is not clear to everyone. There are farmers and crofters who are implementing agroecology as defined by the ten elements defined by the UN FAO and there are others who are adopting some of these principles without a clear understanding of the overall approach. If agroecology is to be implemented widely, farmers and crofters need to know more about agroecology as a paradigm and the associated economic, social and environmental benefits. Many respondents were already implementing agroecological practices even if they were not adopting all aspects of the agroecological ethos, suggesting that agroecology provides a broad and inclusive pathway to sustainability in agriculture. Despite lack of clarity on definitions, many respondents recognised the need for systemic changes in farming and food production to achieve sustainability and resilience in agriculture and to address biodiversity and climate concerns.
- **Concluding remarks:** agroecological farming is more knowledge intensive and less reliant on chemical fixes than conventional modern farming, it demands an understanding of ecological processes in farming systems and integrates the farming operation with the local community and food systems (though social mechanisms). More evidence and greater awareness are needed amongst land managers and other agricultural stakeholders about the financial and social outcomes, as well as the environmental outcomes, of agroecological approaches. Better recognition of current agroecological farming efforts and improved support (i.e. financial, knowledge) could encourage wider adoption of agroecological transitions.

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Introduction

Agriculture is facing unprecedented challenges in producing affordable nutritious food sustainably (IPES, 2016), conserving biodiversity (IPBES, 2019), and storing carbon, while coping with increased climate variability (IPCC, 2021). National and EU policies aim to change how food is produced and consumed to better meet health, climate and nature commitments. To facilitate these strategies and overcome social, technical, and economic 'lock-ins' to existing food systems, agricultural 'innovation ecosystems' approaches are needed to support transitions to sustainable production (Pigford et al., 2018).

An agroecological approach has been proposed by the United Nations' Food and Agriculture Organisation (FAO) to achieve system transformation towards environmental, social and economic sustainability in line with the UN Sustainable Development Goals (FAO, 2018). In the UK, the Food Farming and Countryside Commission (FFCC) set out recommendations in their report 'Our Future in the Land' for a green recovery to transform UK food systems, with agroecological farming playing a pivotal role (FFCC, 2019a). The key features of the agroecological transition paths were defined for the UK (FFCC, 2021a) according to the IDDRI 'Ten Years for Agroecology' modelling exercise, which explored the outcomes for agricultural food production, carbon footprint and environmental impact under the scenario of widespread adoption of agroecology in European farming systems (Poux & Albert, 2018). Application of this model to the UK showed that a transition to agroecology is achievable and would significantly improve the sustainability of agriculture by reducing emissions (at least 50%), increasing the land area used to restore ecosystems, and conserving biodiversity (FFCC, 2021b).

Interpretation of the term 'agroecology' varies between countries, cultures, and other contextual factors (Agroecology Europe, 2020). Amongst the UK nations, Scotland has ambitious strategies for biodiversity protection and climate action with the intention of achieving a greener, fairer future (Just Transition Commission, 2021). It is timely to gather evidence about what is understood by an 'agroecological' farming approach in Scotland and whether it can improve the sustainability of agricultural businesses and their resilience to external factors, including acute external shocks (FFCC, 2019b). The first study of agroecology in Scotland (Ellis & Prager, 2017; van Hulst et al., 2020) highlighted differences between groups in their understanding of what constituted agroecology. There is little information, however, about how widely agroecological approaches are adopted and applied in Scotland to improve agricultural sustainability and whether these deliver beneficial outcomes such as improved efficiency, stabilised incomes, and greater resilience to a range of external factors.

To address this knowledge gap, a SEFARI-funded fellowship project was conducted with the objective of **understanding how the use of agroecological principles can provide enduring benefits for long term land productivity, and the resilience of agricultural businesses in Scotland, including the response to crises such as the Climate Emergency and COVID-19.**

To achieve the aim the fellowship has:

- Investigated the current adoption of agroecological principles by farms/land managers (owners, tenants or contractors) in Scotland through a national online survey; and

- Conducted in-depth interviews to generate a series of Scotland-centred farmer/land manager case studies of strong examples of agroecological practices and shortening of the supply chain.

Defining agroecology

The term “agroecology” was first coined by Bensing in 1928, although the agroecology literature did not develop significantly until the 1960s. Agroecology refers to ‘*a science, a movement, [or] a practice*’ (Figure 1: Wezel et al., 2009). Agroecology implies systems-level thinking (Poux and Aubert, 2018; Hawes et al., 2021) as it is a discipline of integration (Dalgaard et al., 2003).

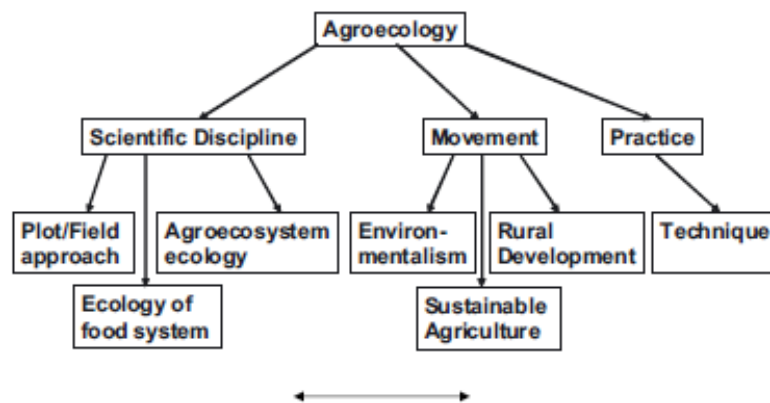


Figure 1. Diversity of current types of meanings of agroecology.

Source: Wezel et al. (2009)

As a **science**, agroecology has been defined as ‘*the integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions, or more simply the ecology of food systems*’ (Francis, 2003). As a **practice**, agroecology is defined as a set of agricultural practices and systems which aims to enhance natural processes and can include (but is not limited to) organic farming, integrated farm management (IFM) and agroforestry’ (Mottershead & Maréchal, 2017). More recently, the term ‘regenerative farming’ has entered common use, referring to farming that uses soil conservation to regenerate and deliver ecosystem services, and enhance the environmental, social and economic aspects of food production (Schreefel et al., 2020). As a **movement** “agroecology” is used by some environmental groups more widely than the management of farming systems, but also ‘*encompassing far-reaching changes to social structures associated with the ownership and tenure of land and the distribution of raw materials and produce*’ (Mottershead & Maréchal, 2017). See **Appendix 1** for more detailed information about the history of agroecology.

The United Nations’ Food and Agriculture Organisation defines agroecology as an integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of food and agricultural systems. It seeks to optimise the interactions between plants, animals, humans and the environment while taking into consideration the social aspect that need to be addressed for a sustainable and fair food system (FAO, 2018).

To achieve the study objective, we adopted the ten elements of agroecology defined by the United Nations' Food and Agriculture Organisation (**Figure 2**), which provide guidance to achieve system transformation towards environmental, social and economic sustainability in line with the UN Sustainable Development Goals (FAO, 2018). These elements include the natural and social dimensions of agroecology, which allows us to disentangle the different components of agroecology and to understand the motivations behind an intentionally practiced alternative agricultural-food system. The elements are grouped in terms of **system characteristics**, **context features** and the **enabling environment** (**Figure 2**).

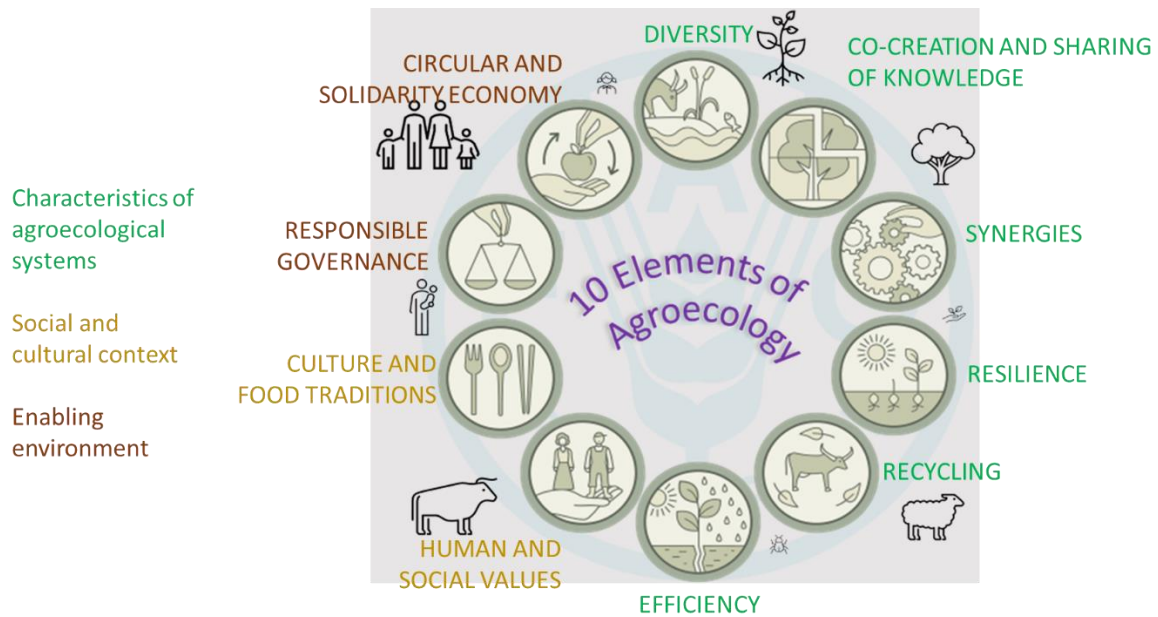


Figure 2. Ten elements of Agroecology as summarised by the UN FAO (2018)

An assessment of the ten elements of agroecology (according to FAO) compared with other terminologies used to describe alternative farming approaches, such as sustainable intensification, ecological intensification, and regenerative farming, is shown in **Table 1** (short version) and in more detail in **Appendix 2**. While specific farming practices (e.g., using less fertiliser or tillage) might be similar across different approaches, there appear to be fundamental differences in their ethos. Sustainable intensification, for example, focusses on increasing agricultural yields without expanding the area of agricultural land while also minimising adverse environmental impact, but with little emphasis on diversification or food system transformation (Pretty & Bharucha, 2014). According to the FAO, the uniqueness of agroecological approaches is that they are driven by bottom-up processes that are knowledge intensive and based on innovations co-created by agricultural stakeholders; they provide autonomy to develop locally adapted solutions and empower communities, including under-represented groups, to bring about positive change (FAO, 2018).

Table 1. Summary of the comparison of alternative farming systems with the UN FAO ten elements of agroecology. See **Appendix 2** for the detailed version.

Agroecology, FAO 10 elements		Sustainable Intensification	Ecological Intensification	Agroecological farming models (Cole et al., 2022)		
				Regenerative Farming/Regenerative agriculture	Organic Farming	Integrated farm management
Agroecological Systems Characteristics	Diversity		✓	✓	✓	✓
	Co-creation and sharing Knowledge					
	Synergies	✓	✓			✓
	Efficiency	✓	✓	✓		✓
	Recycling	✓		✓		✓
	Resilience	✓		✓		
Social and Cultural	Human and Social values	✓		✓		
	Culture and Food traditions					
Enabling Environment	Responsible governance	✓		✓		
	Circular and Solidarity economy			✓		

Characteristics of agroecological systems

Overall goal: The goal of agroecological farming practices is to produce crops in a sustainable way that capitalises on biodiversity, ecological processes and ecosystem services (biological-based systems), whilst avoiding reliance on synthetic crop protection and fertiliser inputs that characterise chemical-based systems (Wezel et al., 2014; Hawes et al., 2021). The term ‘agroecological practices’ has become associated with crop management practices that have long been used to increase soil fertility, reduce pest and disease pressure and optimise yield, for example by using renewable alternatives to agrochemicals, recycling nutrients and waste products, using biological pest control and rotations (Wezel et al., 2014; Hawes et al., 2021). These practices underpin the FAO elements of increasing species and genetic **diversity** of crops and animals, promoting **synergies** between different parts of the farmed system, **recycling** by-products to reduce waste, increasing the **efficiency** of natural resource use and improving **resilience** to pests and disease and external shocks. The need for mechanisms to train and **share knowledge**, whether traditional, indigenous or scientific, between different stakeholders involved in agriculture is widely recognised as important for developing a skilled workforce able to implement agroecological practices and ethos and adapt these to local contexts (Carlisle et al. 2019).

Current situation in Scotland: A large proportion (86%) of Scottish land is classed as less favourable area (LFA) for agricultural production (Scottish Government, 2021). The majority of LFA is managed as

low intensity production systems such as upland rough grazing with very low input levels, and often supported with subsidies; only 2% of the LFA is under arable crops. Non-LFA land accounts for the remaining (14%) land area and is classed as higher quality for agriculture. This land is concentrated in the lowlands of Scotland and tends to be managed intensively for arable crops, predominantly cereals with a smaller proportion used for oilseeds, fruit, potatoes, and vegetable crops (**Figure 3**).

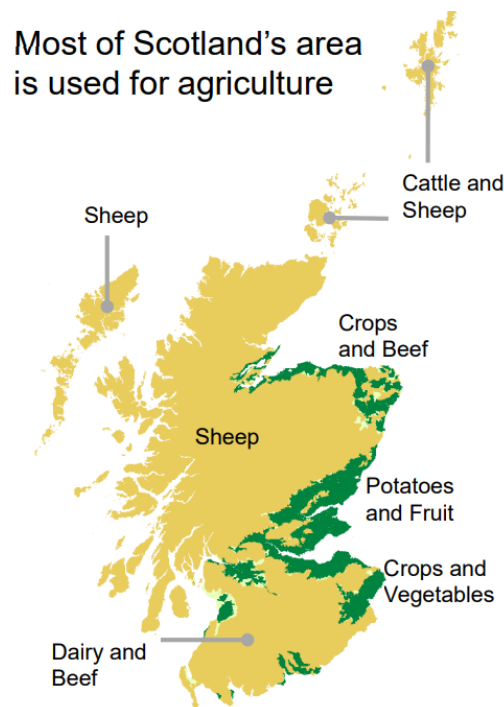


Figure 3. Map of land classifications in Scotland showing areas with limited growing conditions, hill or rocky land suitable for livestock (yellow). Light green areas have better soil and can support crops usually grown for animal feed. Dark green areas can support vegetable, fruit and cereal farming for human consumption. (Scottish Government, 2017).

Five agroecological farming ‘models’ have been identified as commonly adopted in Scottish farming systems (organic, regenerative, integrated farm management, agroforestry, low input farming) in a recent analysis of the climate adaptation and mitigation potential of agroecological practices in Scotland (Cole et al., 2022). The similarities and differences in their associated farming practices showed considerable overlap between the models, ranging from narrow (agroforestry, low input) to broad (integrated farm management, regenerative) in scope (Cole et al., 2022).

Amongst the five agroecological models identified as common in Scotland, only organic is clearly documented in agricultural statistics. Certified organic farmland in Scotland increased slightly in 2017, the first increase since 2008, but was still low (2.1% of agricultural land, accounting for 24% of the total organic land in the UK), compared with 2002 (7.7% of farmed land, accounting for 58% of the total organic land in the UK) and compared with the EU (6.7% of agricultural land across the EU was certified as organic in 2016). In Scotland, grassland and rough grazing account for much of the organic land (93% in 2017), and 2% of cattle and sheep are registered as organic. Cereal production, although on a much smaller area of land, is the second biggest sector for organic farming in Scotland (Scottish Government, 2018). Low input farming can be inferred from the area of LFA agricultural land used for grass and rough grazing production (72% of total agricultural land).

The first published study of agroecology in Scotland found that scientists and farmers had a different understanding of what constituted agroecology (Prager & Ellis, 2017; van Hulst et al., 2020). Farmers were unfamiliar with the term 'agroecology' and associated it with 'sustainable', 'organic' or 'environmental' farming, to which some may have had negative attitudes. Agroecology was mainly understood as being a scientific discipline applying ecological analysis to agricultural systems, but not necessarily to the entire food system (Prager & Ellis, 2017; van Hulst et al., 2020). The farming practices identified by Ellis & Prager (2017) in their initial characterisation of agroecology in Scotland can be grouped by the FAO elements relating to characteristics of agroecological systems (**Table 2**), which reflects how they were incorporated into the online survey for the present study (See **Methods** section).

Knowledge co-creation and sharing in the Scottish agriculture sector is facilitated by knowledge transfer organisations with farmer networks (e.g., Soil Association Scotland, SAOS, LEAF UK, FFCC, Pasture for Life), membership organisations (e.g., AHDB, NFUS, Scottish Crofting Association), commercial agronomy services, agricultural research and teaching organisations (e.g. SRUC, James Hutton Institute) and numerous local community groups.

Table 2. Agroecological farming practices according to Wezel et al (2014) that are relevant to Scottish farming systems* and how they relate to the characteristics of agroecological systems defined by the UN FAO.

	Practice	Diversity	Synergies	Resilience	Recycling	Efficiency
Diversification	Crop rotations	√		√		
	Species-rich grassland	√				
	Intercropping, relay cropping	√				
	New or novel crops	√		√		
	Agroforestry with cropping/grazing beneath	√	√			
	Habitat modification (e.g. field margins, Beetle Banks, hedgerows, trees)	√	√			
	Cultivar choice, cultivar mixing (e.g. pest/disease resistance)	√				
	Crop-livestock systems		√		√	
Pest and disease control	Monitoring and surveillance			√		√
	Threshold monitoring for pesticide use			√		√
	Natural/botanical pesticides			√		
	Biological pest control			√		
	Allelopathic plants	√		√		
	Microbial insecticides			√		
	Targeting antibiotic use			√		√
	Selective use of antibiotics			√		√
Nutrient management	Reduced tillage	√				√
	Cover crops, green manures	√			√	
	Increase soil biomass/carbon			√		
	Precision agriculture (sowing, fertilisation, inputs)					√
	Drainage and water management			√		√
	Nitrogen fixation measures (legumes in rotation or intercrops)	√			√	√
	Recycling organic material (slurry, manure, crop residues, green manure)				√	√
	Mob grazing		√		√	
	Encourage foraging to reduce feed inputs		√		√	

*See Table 1 in Prager & Ellis (2017).

Social and cultural context of agroecology

Overall goal: As a systemic framework, agroecology is much more than a set of specific agricultural, agroforestry and livestock practices. The agroecological approach builds on existing social, cultural and economic conditions to strengthen local communities at the same time as ensuring an enhanced and biodiverse agricultural production linking into local food systems and cultural values. It directly links agriculture with social and economic objectives of sustainable development building on local experience and knowledge while further empowering these through scientific input from agronomy, ethnoecology and social sciences (Reintjes et al., 1992; Altieri, 1992; Martinez Castillo, 2004). The main social and cultural practices of agroecology are the satisfaction of local needs, local food security, integrated rural development, gender and social equity, stability of production, reliance on local resources, economic viability and fairness.

From the holistic view of agroecology, a system of production is agroecological only if it integrates all these socio-economic and cultural factors, or at least most of them, beyond only ecological and agricultural factors.

Re-designing food systems to achieve greater sustainability invokes the need for behaviour change from farm to consumers to shorten food chains and allow farmers and consumers to respond to each other's needs (Gleissman, 2016), strengthening the sense of community and **supporting healthy diets** that respect culture and food traditions. Scaling up this 'food citizenship' network beyond farm-level could allow system level transformation, involving shifts in human and social values and improved food justice, which ultimately would **improve rural livelihoods** in terms of income, social equity, and autonomy.

Current situation in Scotland: Local food initiatives can be found across Scotland, ranging from community supported farms to producer co-operatives to organisations supporting healthy eating. Charitable organisations such as Nourish Scotland, for example, focus on food policy and practice, aiming to represent social, environmental and economic values of food production and consumption that reflect agroecological principles. These initiatives are generally small-scale; empirical research shows that minor changes to farming practices often occur incrementally over time, while 'trigger' events are necessary to induce major transformational changes (Sutherland, 2012), evidenced by shifts in consumer behaviour in response to supply chain issues in the early stages of the COVID-19 pandemic. The draft 'Good Food Nation' (Scotland) Bill, published in October 2021, provides legislation to produce a national good food nation plan, and has the ambition of improving outcomes for social and economic wellbeing, the environment, health, and economic development. The Bill will undergo parliamentary scrutiny in the coming months, and this process might reveal whether the legislation has the potential to support transformational change in Scottish food systems.

Enabling environment: policy and legislation

Overall goal: In the global south, agroecology has political connotations with social and economic justice goals and food sovereignty, but these are less frequently associated with agroecology in Europe and North America. The adoption of agroecology principles and practices in Scotland does, however,

rely on policy and **governance** infrastructures that are transparent, accountable and inclusive to support transformation and overcome barriers to uptake. These infrastructures should ideally aim to bring **producers and consumers closer together** and promote innovative and fair solutions based on local needs.

Current situation in Scotland: Prior to 2021, financial support for UK agriculture was governed by the European Union's Common Agricultural Policy (CAP 2014-2020) under regulations for direct payments to farmers, common organisation of markets, rural development support, management and monitoring¹.

Implementation of CAP in the UK has supported some aspects of agroecological farming through cross-compliance rules on soil protection, water quality, animal welfare, wildlife conservation, greening measures, and agri-environment schemes. All countries of the UK provide support for conversion to organic farming, and the food and agriculture industry in Scotland has been developing an Organic Action Plan in close collaboration with the Government (Scottish Government, 2016). Scotland, Wales and Northern Ireland also provide specific support to agroforestry through CAP implementation, although in some cases they are modest. Scotland's Rural Development Programme, for instance, has a budget of €1.2 million for agroforestry with a target to cover 300 hectares.

In November 2020, the UK Agriculture Bill came into law providing legislation for how farmers and land managers in England will be rewarded with public money for 'public goods'; a seven-year transition period is underway to replace the CAP Basic Payment Scheme subsidies with the 'Environmental Land Management' scheme (ELMs), which aims to support measures that improve soil, air and water quality, support wildlife, and deliver net zero carbon targets. Three pilot incentive schemes are being launched, which will pay for actions to i) support sustainable farming practices and profitable food production, improve animal health and welfare, improve environmental outcomes, and reduce carbon emissions (Sustainable Farming Incentive), ii) create habitats for nature recovery (Local Nature Recovery scheme) and iii) make landscape scale changes to establish woodland and support ecosystem services (Landscape Recovery scheme).

Scotland has an ambition to be a world leader in 'green' farming for which it envisages a strong role for mentoring, training and on-farm advice ("The Future of Scottish Agriculture" 2015) to support farmers in achieving environmentally and commercially successful management in the running of their businesses. The Agriculture (Retained EU Law and Data) (Scotland) Bill was passed in August 2020 to allow continuation of the CAP in a transition period following EU exit and provide opportunities to improve the scheme. The development of Scotland's agricultural policy post-CAP has focused on six farmer-led groups, which were created to synthesise knowledge and recommend ways agriculture can tackle climate change; the adoption of these recommendations into agricultural policy has been published for citizen consultation on an 'Agricultural transition in Scotland'. The consultation included consideration of actions to enhance biodiversity and wider environmental benefits, improve animal welfare, soil and crop health, meet climate change targets, and develop 'green' credentials for Scottish produce.

¹https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en#documents

Scotland's Third Land Use Strategy (2021-2026) published in March 2021 sets out objectives and policies to achieve sustainable land use, as well as habitat restoration and creation to support 'High Value Nature farming' (Climate Change Plan update, 2020) and Scotland's Environment Strategy (2020). While agroecological farming methods are not specified in the strategy, the preservation of natural assets to support ecosystem services is at the heart of the strategy's vision for sustainable land use, alongside greater social equity in a green recovery as part of a 'Just Transition' to net-zero. These social and cultural aspects of agroecological principles are reflected in the Environment Strategy (2020) and in the Scottish Government's aspirations for sustainable food systems (Good Food Nation, 2014) that produce nutritious and environmentally sustainable food that respect culinary heritage and support healthy diets and improved wellbeing. Concern over the environmental impact of farming and desire for greater use of sustainable farming methods (including organic) were highlighted by respondents to the consultation (in 2019) on proposals for legislation to deliver the Good Food Nation (Good Food Nation Programme of Measures, 2018).

Taken overall, the strategies and action plans published by the Scottish and UK governments show a consistently strong appreciation of the need for production to respect environmental limits, of the role of knowledge, best practice and advice in helping to achieve this, and of the need for the necessary changes in agriculture to be supported by research and training. Unlike the EU, however, which has set ambitious targets in the Farm-to-Fork strategy for pesticide use (50% reduction), nutrient losses (50% reduction), fertiliser use (20% reduction) and conversion of organic (25% farmland), there are currently no targets for sustainable (agroecological) management of farmland in the UK.

Theoretical approach and methodology

To achieve the research aim, we use two central concepts to develop the research:

- The ten elements of agroecology defined by the Food and Agriculture Organisation of the United Nations are used to frame and guide our analysis of farmers' practices and whether the farming system could be classified as agroecological.
- Farmers and land managers as agents who take the decision to implement farming practices and whether they recognise the wider benefits or dis-benefits from these practices.

Agroecological principles and farming practices are a farm systems choice for farmers and land managers who freely decide to implement them. Literature on the factors influencing farmers' choices and decision making is abundant (e.g., Sutherland et al., 2012) and will not be discussed in detail here. Instead, we take a slightly different perspective and examine the social, economic and environmental outcomes of decisions to farm agroecologically. Since the implementation of agroecological farming systems is chosen freely by farmers and land managers in Scotland, it provides the opportunity to question how these choices actively structure and create specific social structures.

We were interested in the interactions between the choice of individuals to practice agroecology and how through these practices farmers and land managers participated in the "wider society and at the same time how [they] actively structure that society in [their] own actions" (Giddens, 1997). Giddens' structuration theory refers to "the rules and resources drawn upon in the production and

reproduction of social action are at the same time the means of system reproduction. The constitution of agents and structures are not two independently given sets of phenomena, a dualism, but represent a duality". Structuration theory is about how people's practices are creating social structures and at the same time these social structures make practices possible. People's actions (re)create the structures that at the same time condition their actions. People can change and create new structures through actions which, however, are conditioned by the previous structures. We used structuration theory to understand how farmers and crofters are agents of change, and if and how their actions are creating or changing social structures that will allow them to continue reproducing or developing their farming systems

To achieve the aims of this research we collected both qualitative and quantitative information, by conducting an online survey (see survey in **Appendix 3**) and recording ten in-depth phone interviews (see interview guide in **Appendix 5**).

The criteria for identifying research participants for the online survey was that they were farmers or smallholders farming or crofting in Scotland. Online surveys are biased by self-selection. However, an online survey was the best available method in the available time to reach as many farmers as possible. The first study of agroecology in Scotland focussed on stakeholders' understanding of the term agroecology (Prager & Ellis, 2017; van Hulst et al., 2020); to our knowledge, the current study is the first to analyse the adoption of agroecological farming practices in Scotland and the underpinning motivations.

Online survey participants were recruited by advertising through existing stakeholder networks and/or memberships of the project partner organisations reached through website news items, newsletters and social media. To increase the response rate and broaden the survey recipients as widely as possible, we contacted organisations and associations which could distribute the questionnaire to their Scottish members (e.g., NFUS, LEAF, GWCT, Scottish Crofting Federation, etc.). These methods were successful in eliciting responses from across Scotland, although analysis of the responses indicated the participants were not a representative subsample of the Scottish farming sector (e.g., in terms of age, gender, farm type). The survey was open for over two months from 21st of June 2021 to 30th of August 2021. Weekly and/or monthly reminders were sent to organisations to invite their members to fill the survey. R software and the Qualtrics reporting tool were used to analyse the data.

The ten in-depth interviews were carried out to better understand how farmers/land managers adopt and implement agroecological principles, with participants recruited from existing contacts of the project partners and those who volunteered themselves after responding to the online survey. We aimed to conduct interviews spanning a range of farm and business types that characterise Scottish agriculture, including crofting, lowland and upland systems, and covering livestock, arable (combinable and horticultural crops) and mixed farming. NVivo software was used to analyse the qualitative data.

The online survey was designed with 17 questions, written in simple language to avoid confusion or influencing questions, and to be as free as possible from moral values. Most questions were designed in a closed format to minimise the time taken to complete the survey and to permit analysis. The interview questions were designed for flexible discussion around the FAO's ten elements of

agroecology with an intended duration of 60-90 min. To avoid informants experiencing research fatigue, research participation was completely voluntary, and consent was obtained from all participants.

This research did not collect sensitive personal data and interviewees were anonymised in survey datafiles, and interview transcripts and recordings; coded pseudonyms were used for interviewees quoted in this report. Ethics approval was secured from the Hutton Research Ethics Committee and the Scottish Government Rural and Environmental Science and Analytical Sciences Division (RESAS) prior to the online survey going live and prior to contacting interviewees.

Results

Online survey

Data was collected through the online survey regarding the characteristics of respondents, their farm management approach and use of 25 farming practices as identified by Ellis and Prager (2017), and their implementation of the ten elements of agroecology as defined by the FAO. See **Appendix 3** for the full online survey questionnaire.

251 questionnaires were returned and 192 were fully or partially completed, with responses received from across Scotland (**Figure 4**) and from all farm types.

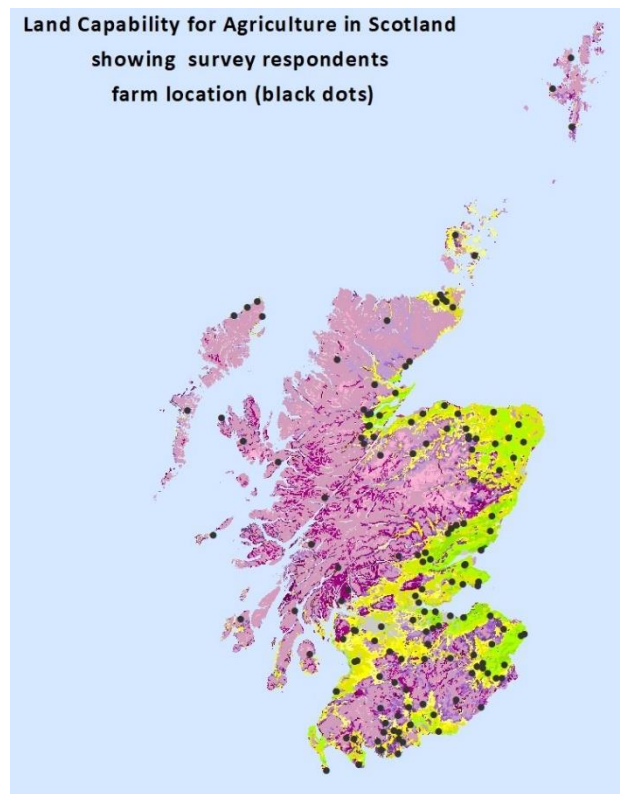


Figure 4. Geographic distribution of participants in the online survey.

Out of 143 respondents, less than half (60) relied on farming or crofting as their main source of income (i.e., an average of 80-100% of their income). The median percentage of their income obtained from

the respondents' farming or crofting activities was 66% (range: 2% to 100%). The area of land managed by respondents ranged from 1 ha to 2,709 ha, with a median value of 109 ha (270 acres).

Respondents represented the main categories of farming enterprises in Scotland (**Appendix 4: Figure S1**), including livestock (56%), combinable crops (10%), horticultural crops (potatoes, vegetables, fruit: 10%), dairy (3%) and renewable energy crops (4%). A small proportion of respondents carried out additional activities including tourism accommodation (7%) and farm shop sales (2%). Farm location types captured in the survey covered lowland farms (38%), upland/hill farms (44%) and registered crofts (12%) (**Appendix 4: Figure S2**).

Characteristics of agroecological systems in Scotland

Respondents were asked to categorise their approach to farm system management (**Figure 5**). The largest category (31%) of respondents classed their approach as conventional, followed by regenerative farming (20%), agroecological (17%) and organic (11%), which likely reflects greater organic representation than might be expected for the whole of Scotland (2.1% land managed as organic in 2017). Overall, c. 60% of respondents farmed using an approach that could be classed as agroecological (i.e., organic, pasture for life, LEAF, regenerative, permaculture and agroecological), a high figure that is unlikely to be reflected across the entire Scottish farming sector. In some of the analyses presented below, we have combined the 'agroecological' management approaches into a single category to allow comparison of answers from respondents using conventional, agroecological or both farm management approaches.

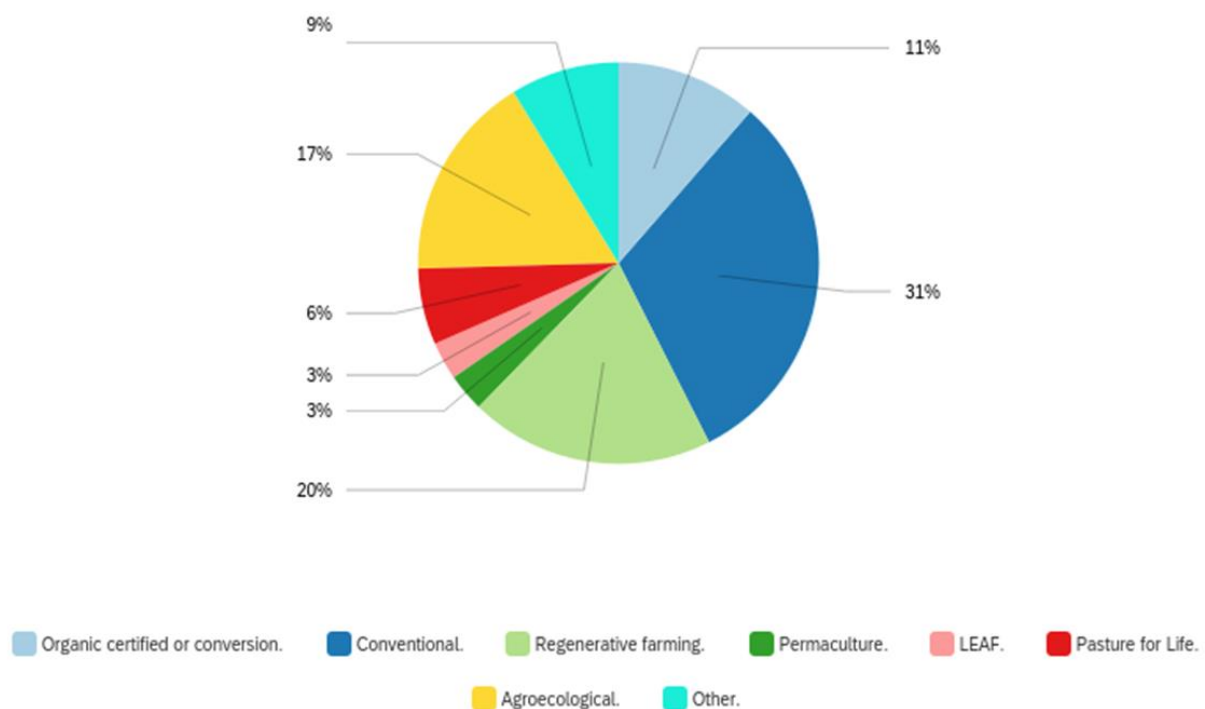


Figure 5. Farm system management approach used by participants in the online survey.

Farming practices. Respondents were presented with a list of 25 farming practices that are associated with agroecological approaches. Most practices were used by at least some respondents (**Figure 6**). The most common practices were those used for soil management (tillage, soil nutrient inputs,

drainage) corresponding to practices of **recycling** and **efficient use of natural resources**. Practices underpinning **diversification** were moderately common (crop rotation, grassland composition, non-crop habitat management) while **resilience to pests and disease** mostly related to monitoring for issues and targeted antibiotic use. Practices to promote **synergies** were variable (encouraging foraging, integrated crop and livestock systems). On average, respondents applied these practices on 76.5% of their land (from 145 responses). Significantly more of these practices were used by respondents who used farm management that could be classed as agroecological (median of 10 practices) or both conventional and agroecological practices (median of 10.5) compared with those using conventional management (median of 5 practices).

Farming Practices

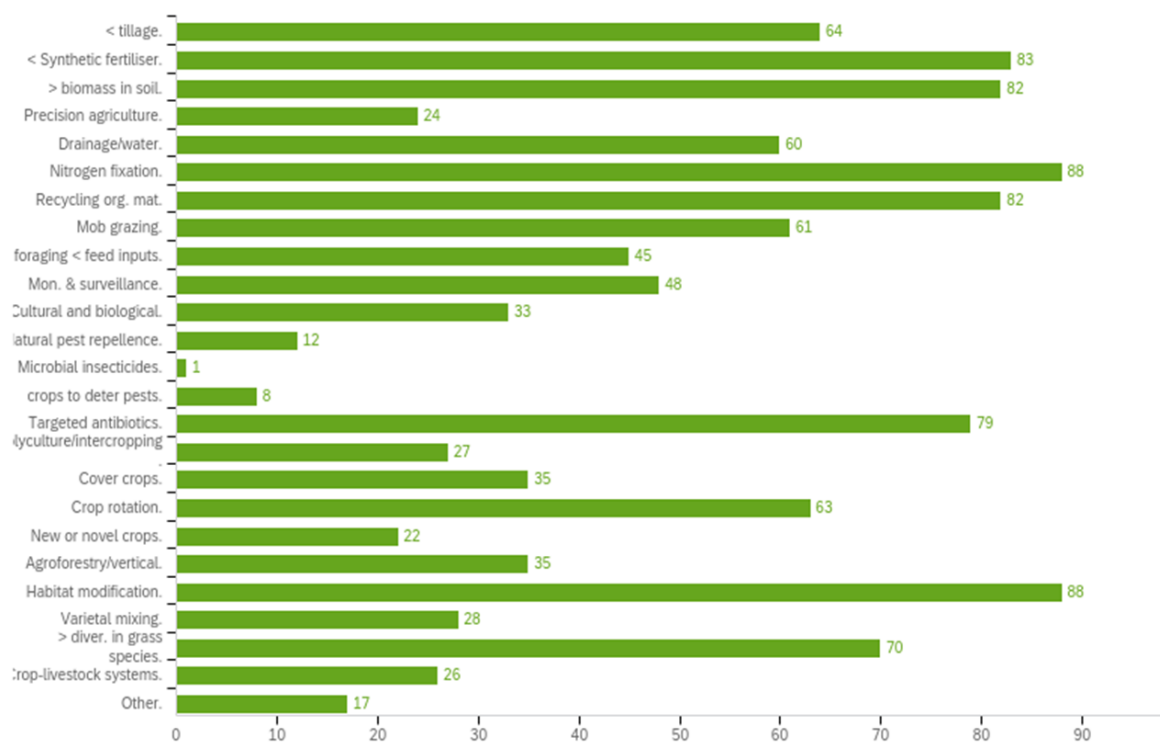


Figure 6. Frequency of use of farming practices classed as ‘agroecological’. Significantly more of these practices were used by respondents who used farm management that could be classed as agroecological or both conventional and agroecological practices compared with those using conventional management (Kruskal-Wallis one-way analysis of variance: $H_2=32.68$, $p<0.001$).

Farming objectives. Respondents were asked to provide their reasons for applying their specific set of farming practices and whether these related to ecological outcomes or other outcomes (e.g. financial). The motivations were mostly to improve soil health and biodiversity and reduce inputs (**Figure 7**). Reducing pollution, improving weed, pest and disease control, and improving finances were also cited.

Respondents were asked whether and how their farming practices had helped their farm business to cope better with external shocks. The majority (88%) of responses were positive: approximately 40%

of respondents thought their farming practices had increased farm resilience by improving soil health and biodiversity conservation, 30% said it had improved financial strength of the farm business and 16% said it had led to other improvements (**Figure 8**). The number of these outcomes (out of a total of 7) achieved by respondents was significantly higher for those using farm management that could be classed as agroecological (median of 5 outcomes) or both conventional and agroecological practices (median of 4 outcomes) compared with those using conventional management (median of 2 outcomes) (**Figure 8**). More of these outcomes were achieved by respondents applying a higher number of the agroecological practices described above (**Figure 6**). Further, more respondents across all land ownership categories either strongly agreed or agreed than disagreed with the statement that: ‘Ecological measures and recycling practices within the farming system reduce costs and dependency on external resources, making farmers more independent and better prepared for external crises (economic, climate, or other)’ (**Appendix 4: Figure S7**).

Objective of carrying out these practices

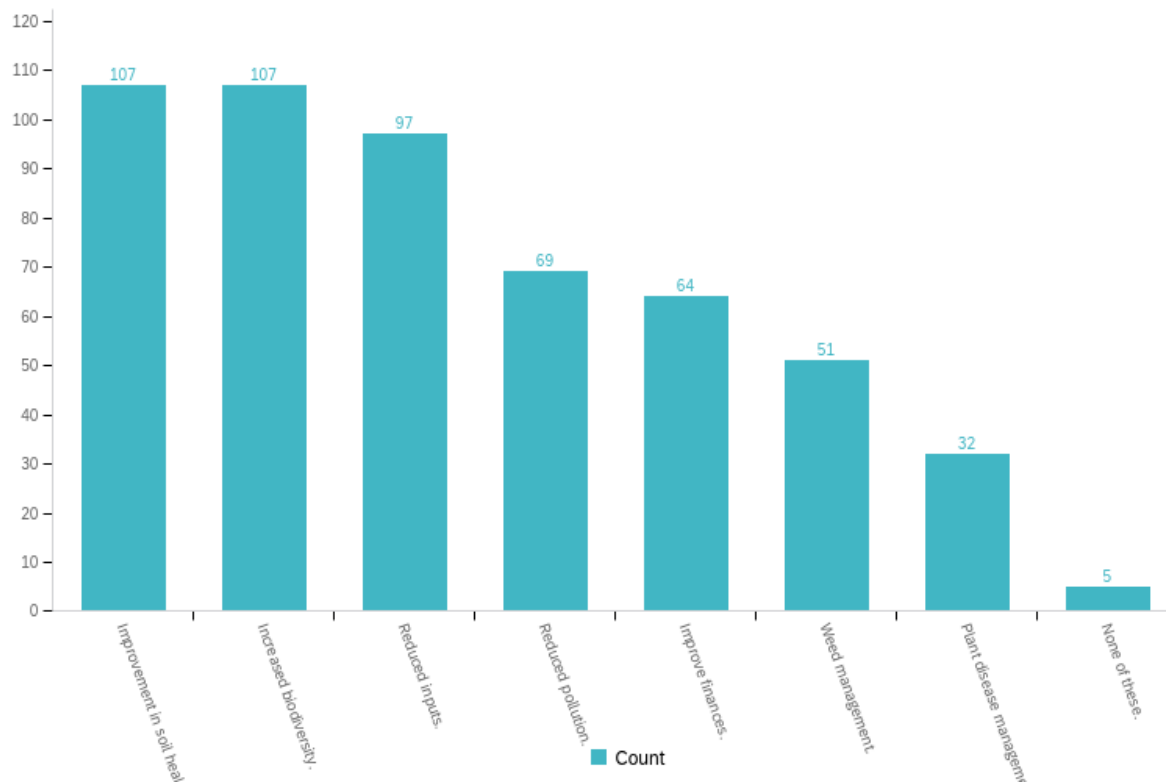


Figure 7. Motivation of respondents for applying their specific farming practices.

Helped the farm to better cope?

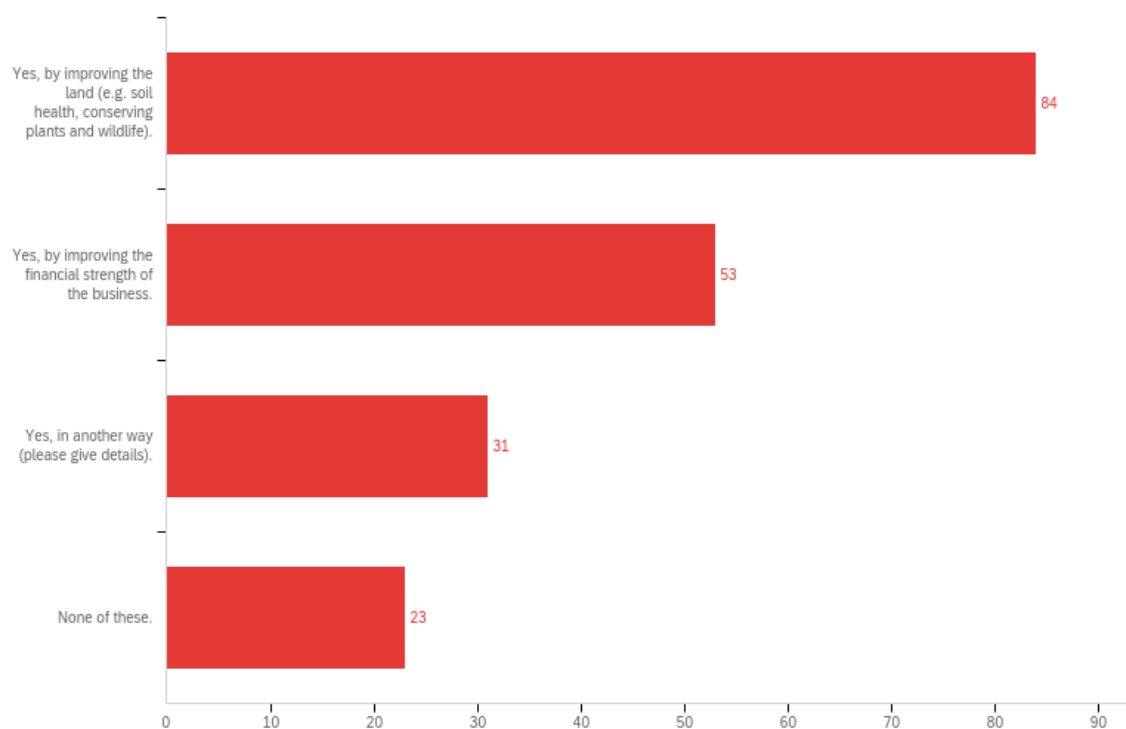


Figure 8. Outcomes experienced by respondents from applying their specific farming practices. The number of outcomes (out of a total of 7) achieved by respondents was significantly higher for those using farm management that could be classed as agroecological or both conventional and agroecological compared with those using conventional management (Kruskal-Wallis one-way analysis of variance: $H^2=33.22$, $p<0.001$). More of these outcomes were achieved by respondents applying a higher number of the agroecological practices shown in **Figure 6** (correlation coefficient = 0.669, $p<0.001$).

Respondents were asked where they obtained advice and information about new farming practices. More than two-thirds obtained new information at least partially through their own research and experimentation (**Figure 9**). A significant proportion of respondents consulted others, indicating widespread use of the agroecological principles of **co-creation and knowledge sharing**; female respondents were slightly more likely than males (41% vs. 34%) to consult others (family, friends, neighbours, farming networks) and less likely than males (11% vs. 23%) to use paid services of agronomists or trade representatives.

New knowledge by gender

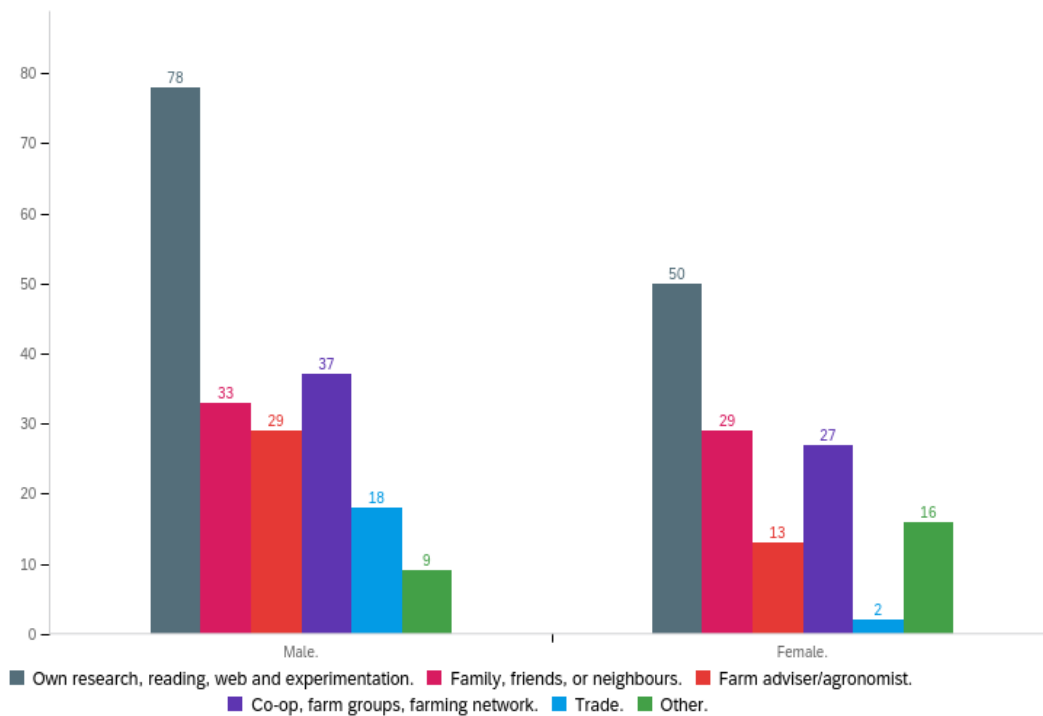


Figure 9. Sources of advice and information used by respondents about new farming practices.

Social and cultural context of agroecology in Scotland

Age group and gender. Out of the 192 responses, 76 (40%) were from the 51-to-65-years age group, and 61 responses (31%) from the 36-to-50 years age group. This reflects the overall Scottish Government 2020 agricultural workforce figures (37% are under 54, 29% are 55-64, 34% are >64). Regarding gender, 77 of respondents were female (40%) and 111 were male, which is greater than female representation in the overall Scottish agricultural workforce (23% in 2020), and three preferred not to answer the gender question.

As can be seen in **Figure 10**, the respondents from the age group of 66 years and older were mainly male: 19 male and 3 female. The other age groups had slightly more male respondents, although there was good female representation. The results are not significantly different from national figures for the farming sector, except for the >66 age group which had significantly more male respondents compared with the overall agricultural workforce (66% male in 2020: Scottish Government, 2021).

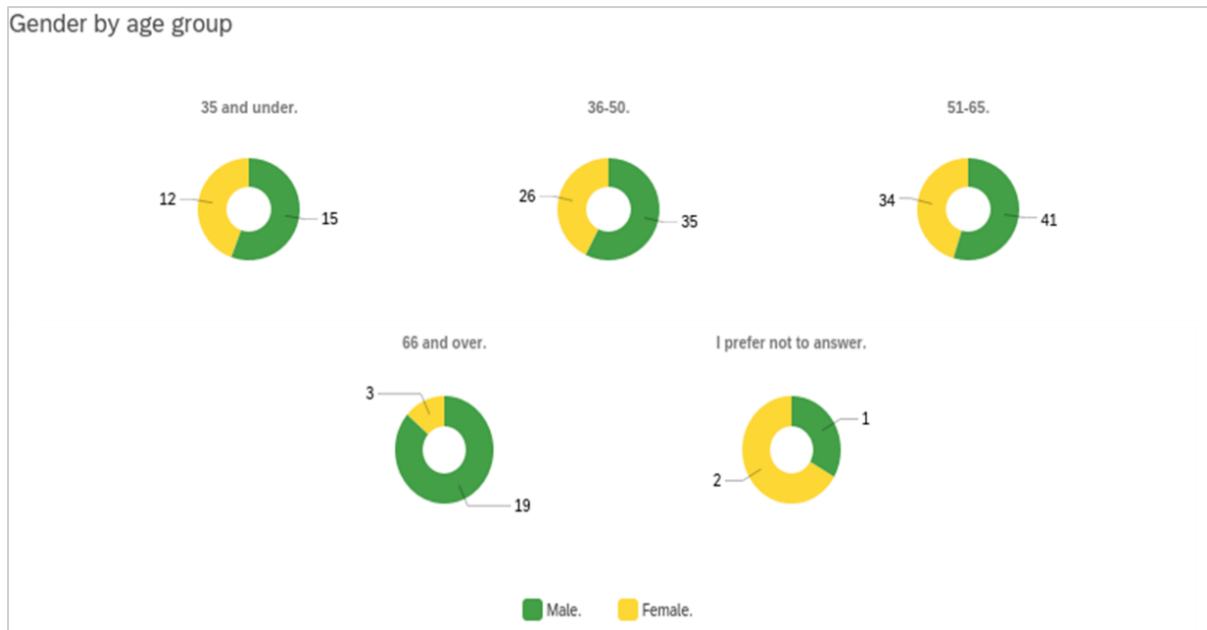


Figure 10. Gender composition of each age group of participants responding to the online survey.

Tenure. Most of the respondents were landowners (125 out of 195 responses, or 64%). There were 33 tenants (16%) and 19 crofters (10%), with 14 (7.2%) classed as other types of tenure or land use agreements which included the following:

- Use of land for free with permission of landowner, no legal agreement
- Co-operatively owned
- Informal grazing arrangement
- Annual grazing let
- Tenanted hill farm and owned lowland farm

Within the 33 tenant respondents, almost half of these had tenancies under the Secure tenancy 1991 Act (13 responses); the other tenants comprised crofts (6), 15-year Limited Duration Tenancy (3), 5-year lease (1), fixed term (2), informal arrangement (2), Limited Partnership (2), Short Limited Duration Tenancy (7), and Smallholder (1). The land ownership category was male-biased, but all other categories were gender balanced (**Figure 11**). Application of farm management approaches was reasonably consistent across land tenure categories (**Appendix 4: Figure S3**).

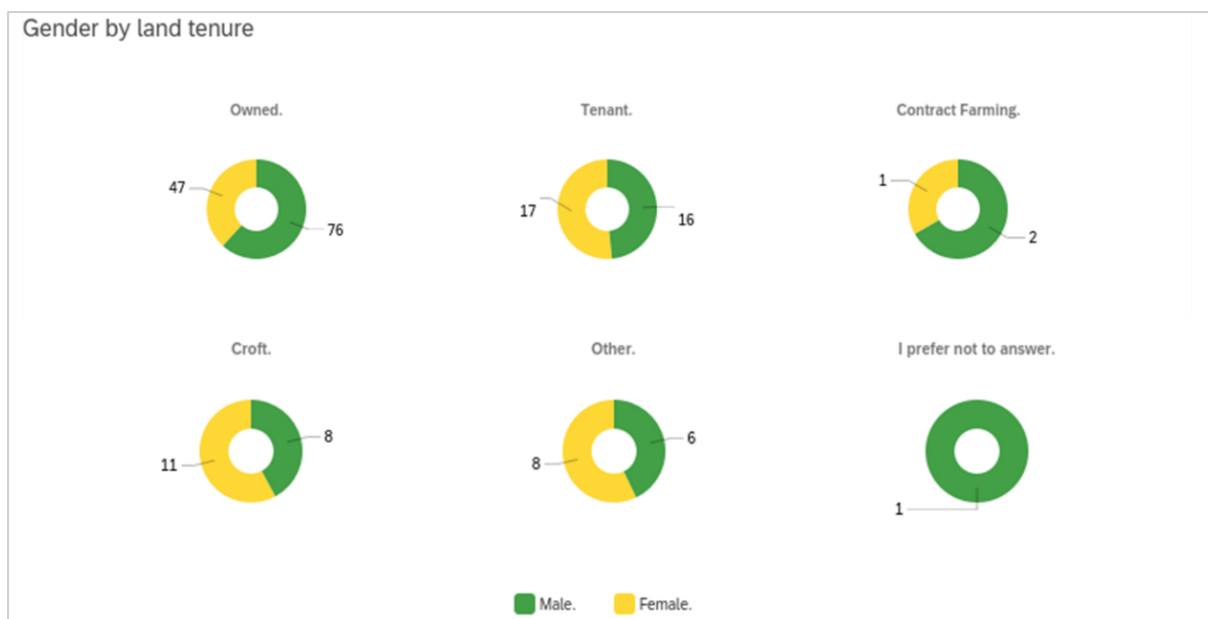


Figure 11. Gender composition of land tenure for participants responding to the online survey.

Number of generations in farming. Participants were asked how many generations of their family had been in farming to explore if a farming background had an influence on how the land was farmed, whether knowledge was transferred and/or how they changed from previous generations, and whether new entrants had other innovative forms of managing the land. Most respondents (70%) had previous family involvement in farming: 79 respondents indicated “their grandparents were in farming”; 31 respondents stated, “their parents were in farming” and 46 respondents were “new entrants” (**Appendix 4: Figure S4**).

The number of participants who responded that “their grandparents were in farming” and “their parents were in farming” (total of 110 answers) and 46 “new entrants” were plotted against the system management they have in place (**Figure 12**). This showed that 62 of the respondents with a farming background (“their grandparents were in farming” or “their parents were in farming”) have a conventional farming system, compared to 7 new entrants managing as conventional. The other management systems are also mainly from participants with a farming background, except for the explicitly agroecological management, which had more “new entrants” practicing agroecology than those with a farming background.

The results show a trend for explicitly agroecological management systems being over-represented among new entrants. Among the respondents, several new entrants started farming in 1976 and the most recent started in 2018.

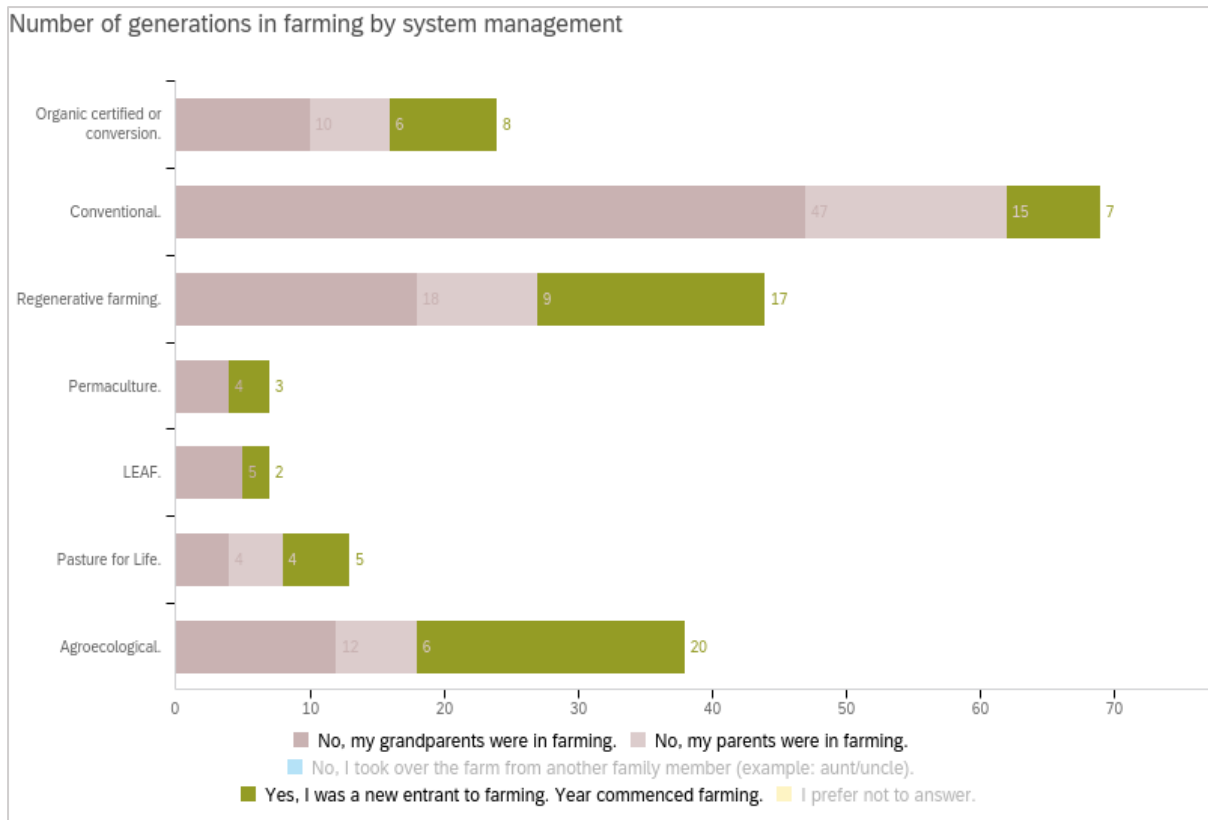


Figure 12. Type of farming practice in relation to the number of generations that respondents and their families had been involved in farming.

Respondents' answers to a series of statements in the survey gave an insight into the **human and social values** of their approach to farming and how these related to improving rural livelihoods (income, social equity, autonomy). More respondents across all land ownership categories strongly agreed/agreed than disagreed with the statement that 'Scotland needs more diversified farming systems that produce food, protect the environment and are resistant to external shocks' and that 'Advice and training need to be more readily available to make farming systems more sustainable' (**Appendix 4: Figure S9 and S10**, respectively). Further, more respondents across all land ownership categories strongly agreed/agreed than disagreed with the statement that 'Modern food habits are disconnected from local food production, local food traditions and sense of place', indicating awareness about farming's role in supporting diets that **respect culture and food traditions** (**Appendix 4: Figure S8**).

Enabling environment for agroecological systems in Scotland

Approximately half of respondents (51%) made use of environmental or rural stewardship schemes, and this was consistent across agroecological and conventional farming systems, indicating those using agroecological approaches were just as likely to access incentive schemes as their conventional farming counterparts. Respondents' answers to a series of statements in the survey gave an insight into the significance attached to **responsible governance** in agricultural transformation. More respondents across all land ownership categories strongly agreed/agreed than disagreed with the

statement that 'It is possible to produce healthy food on the same piece of land whilst protecting the environment and mitigating and adapting to climate change' and that 'Diversification, sustainability and agroecology farming systems are the future for farming in Scotland' (**Appendix 4: Figures S5 and S6**, respectively). Further, more respondents across all land ownership categories strongly agreed/agreed than disagreed with the statement that 'The farming business is more robust to external forces when it is strongly linked with the local community and involves a diversity of people', indicating awareness about the importance of reconnecting producers and consumers for and innovations based on local needs – which underpins the **circular and solidarity economy (Appendix 4: Figure S11)**.

Understanding of agroecology in Scottish agriculture

Respondents were asked to say whether they agreed or disagreed with a series of statements about the potential for agroecological farming to deliver benefits for food production, biodiversity and the environment, and resilience to external crises (see statements 1-3 on page 16, **Appendix 3**). Most respondents agreed or strongly agreed, although a proportion were unsure, and this pattern was consistent across different land ownership categories (**Appendix 4: Figures S5-S7**).

Respondents were also asked if they agreed or disagreed with a series of statements about potential agroecological improvements (agronomic, social, economic) that could be made to modern farming and food production systems (see statements 4-8 on page 16, **Appendix 3**). Again, most respondents agreed or strongly agreed with agroecological improvements, although a proportion were unsure, and this pattern was consistent across different land ownership categories (**Appendix 4: Figures S8-S11**).

Overall, respondents were more likely to agree with these statements if they used farm management that could be classed as agroecological (median of 1.4, where 1 = strongly agree and 5 = strongly disagree) than if they used both conventional and agroecological practices (median of 2.1) or only conventional management (median of 2) (Kruskal-Wallis one-way analysis of variance: $H_2=41.08$, $p<0.001$). Similarly, respondents were more likely to agree with the statements if they were applying more of the agroecological practices described above (correlation coefficient = -0.409, $p<0.001$).

Respondents were asked to read a definition of agroecology (see bottom of page 16, **Appendix 3**) and how this related to their experience of farming. Respondents were more likely to be familiar with agroecology and have experience of using agroecological practices if they used a farm management approach that could be classed as agroecological (organic, regenerative, permaculture, LEAF, Pasture for Life, agroecological: **Figure 13**); those practising conventional farm management were less familiar with the term and were more likely to encounter barriers to implementing agroecological practices (**Figure 13**).

Definition by farm system

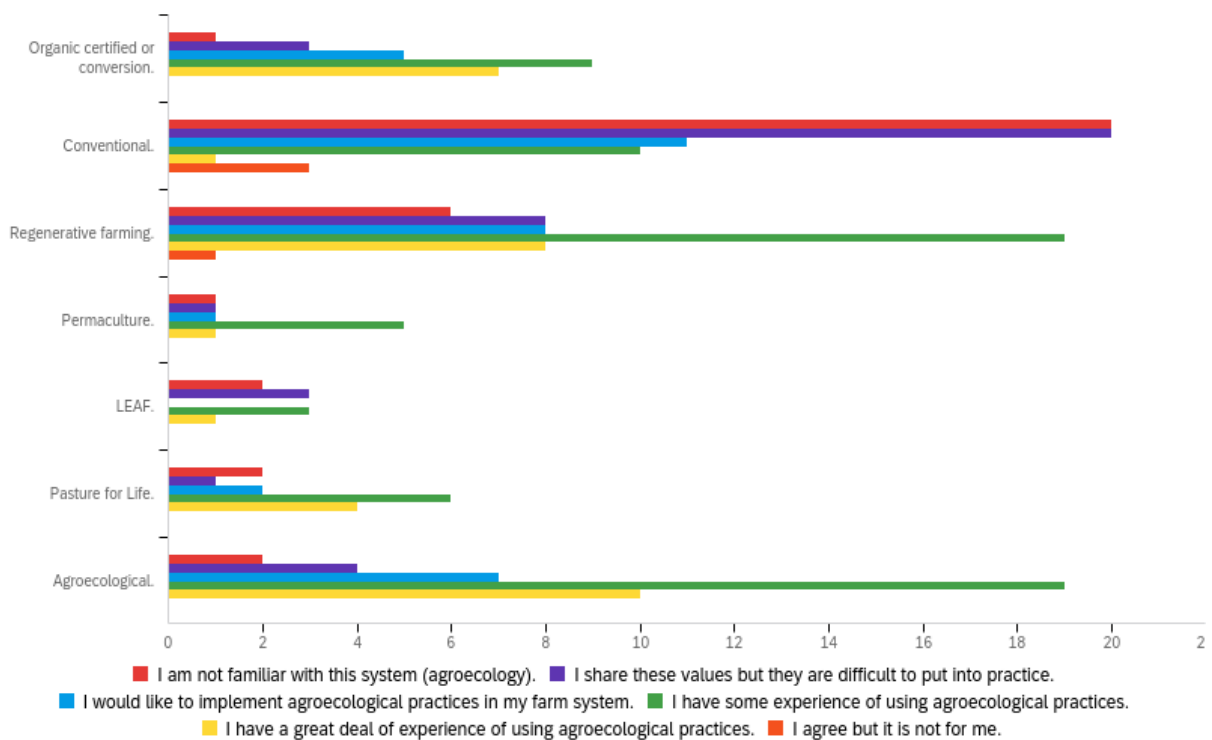


Figure 13. Familiarity of respondents with agroecology and experience of implementing agroecological practices.

Interviews

Interviews were conducted with ten case studies spanning crofting, livestock and community supported agriculture, producing meat, vegetables, fruit and renewables, alongside associated farming businesses (Table 3). The case studies did not include farms in the categories of dairy farms or farms producing intensive cash/combinable crops. At least four of the case studies self-categorised as agroecological in approach, and interviewees were predominantly female (7 out of ten).

Interviews were transcribed and analysed using NVivo software (version 12 pro) to elicit agroecological practices analysed with the FAO's ten elements of agroecology.

Overall, the interviews showed that all informants are aware of the characteristics of agroecological systems, if not in the definition of these, at least in practice. By **diversifying** their systems through **co-creation of knowledge**, experimenting, observing, and changing practices they have achieved synergies and adapted their farming systems to their local context. Agroecological systems require ecological knowledge and all informants in this project mentioned different forms of continued learning processes from searching online, talking to experts and neighbours, and taking inspiration and ideas from other parts of the world.

Table 3 Characteristics of the ten farms interviewed as case studies

Case study site (with coded pseudonyms)	Farm business	Characteristics
1. Perthshire (Paisley)	Breeding sheep soft-fruit and trees renewable energy/biomass tourism (B&B, self-catering) art and distillery	New entrant (since 2008) Lowland livestock, managed with regenerative farming, permaculture and agroecological principles (7 acres)
2. Inverness-shire (Catriona)	Sheep farm vegetables and fruit online food hub and Tea Rooms	New crofting entrant (704 acres)
3. Inverness-shire (Erskine)		No chemical inputs, uses recycled organic waste, crop rotation etc. (12 acres)
4. Aberdeenshire (Isla)	Grazing livestock	New entrant (100 acres) Farming owned and rented land using regenerative agriculture methods
5. Lothian (Skye)		Lowland mixed farm (270 acres)
6. Dundee (Leana)	Cows, sheep for meat	Upland livestock (1100 acres) Organic for 15 years
7. Inverness-shire (Dylan)	Water buffalo pigs, sheep goats, hens	New entrants Lowland livestock (47 acres)
8. Lothian (Mackay)	Potatoes, vegetables pigs, poultry Restaurant	Community Supported Agriculture (100 acres) Membership club
9. Fife (Alba)	Vegetables, salad, herbs and fruit	Community Supported Agriculture (2 acres) Managed using agroecological principles New entrant (since 2008)
10. Berwickshire (Ailsa)	Cattle, pigs and sheep butchery	Family business started in 1990 (650 acres) Organic and Pasture for Life management

Although informants did not measure the efficiency of running an agroecological farming system, all of them recognised the **resource-use efficiency** of diversifying and creating **synergies** between different components of their farming system. In small scale farming systems, measures to create synergies and resource-use efficiency are planned carefully through time and space - over the seasons of the year and across their land. Informants mentioned different types of **resilience**, including environmental, economic and social resilience at farm level and at community level.

Regarding the **social and cultural context**, interviewees saw the benefit of selling their products locally as it allows some to sell at a premium price while for others it is in their business model to connect with consumers directly even if selling without a premium (fairness, as a social value). Doing so they recreate a community by engaging people from local and wider communities with the farm either by personally sharing information on the products and their farm's ethos or by selling on the farm itself

where customers have a first-hand insight into the farm. An important element of these practices is to reconnect food production with consumers, shortening the supply chain and filling the gap in knowing where the food comes from. However, they feel that the wider community and the general public do not always understand crofting or farming systems, or that there is a pressure on farmers in general to restore biodiversity, mitigate climate change and produce food but at the same time they are blamed for the way they have been producing food. Lastly, interviewees did not find major barriers for women to enter farming. They mentioned that this was an issue for previous generations, but it is not encountered as a barrier in current times. The main issue creating unfairness stressed by interviewees was access to land and the issue of retaining land for a long period, which is intrinsic to the development of agroecological farming systems.

Agroecology is **not only about money**: “...essentially I don’t really care that much about the money but obviously I need it but how can we produce food and valuable produce from this land without damaging it and if we can do that by enhancing the habitat...but I also think that the better the land is doing the better my agricultural business is going to do”.

Below we present these findings from the interviews in more detail. To carry out the analysis of the ten interviews, we structured the findings around the FAO’s ten elements of Agroecology.



Figure 14. Qualitative analysis using the FAO’s 10 elements of Agroecology.

Characteristics of agroecological systems in Scotland

FAO element 1: Diversity. Agroecological diversification for food security and nutrition while conserving, protecting, and enhancing natural resources.

***“I think that the more diverse you are on a croft then obviously the more autonomy you have”
(Erskine).***

We found that most interviewees have implemented a number of farming practices allowing diversification to happen. Some of these practices are:

- Polytunnel intercropping
- Cover cropping *“but at the same time as trying to get things to cover the soil in between stuff that is a bit tall and leggy”*(Catriona).
- Having an important diversity of grass species
- Managing over 40-50 different vegetables
- Small-scale agroforestry: *“we are doing agroforestry in a small way so we have lots of willow for windbreak but that we then chip into woodchip compost”*(Alba).
- Seed diversity: *“we save some of our own seed and we’re trying to get better at doing that so we can have seeds that’s adapted to our conditions here (like the Sutherland kale, the Ailsa Craig tomatoes, we work with like a network of seed savers to try and preserve some of those varieties)”* (Alba).
- Improve grazing biodiversity through wildflower meadows under orchard grazed only in late autumn.

Informants also mentioned the need for balance and for knowledge of the land to diversify accordingly and that diversification enables more autonomy on the farm or croft. As mentioned in the interviews:

“I think that the more diverse you are on a croft then obviously the more autonomy you have because if you work a single crop which might be sheep and lambs then you’re completely dictated to by market conditions and by the subsidy regime and you have to work” (Erskine).

FAO element 2: Co-creation and sharing of knowledge. Agricultural innovations respond better to local challenges when they are co-created through participatory processes.

“... we experiment, and we try things and we learn things” (Skye).

“we keep things in balance and ...it’s probably a situation we’ve reached by accident because as I say we’re not scientific at all its just observation and experience” (Erskine).

We found that interviewees acquire new knowledge through the internet, reading books, social media and farmer to farmer groups. As part of the process of acquiring new knowledge, informants mentioned that through observation, experimentation, testing and trial-and-error they learn about which practices give them the desirable results. As one interviewee mentions:

“I’m just trying anything to see what grows so my...the orchard and the soft fruit and everything I’ve just planted, loads of different varieties, just to see what’s going to do the best so that in the future I can go with them a bit more” (Paisley).

This approach of learning-by-doing requires different lengths of time to follow through the experimenting and learning processes: learning can take anywhere between a single day to years.

There were no notable gender differences regarding learning processes. However, some interviewees mentioned that there are more female farmers/land managers introducing new things like *“bringing an old croft back into production, or just trying a slightly different type of farming”* (Catriona).

Peer to peer learning appeared to combine knowledge exchange with immediate peers as well as through wider networks:

“Then just the last year or two I sort of developed a network of people that I know enough people now that I can ask questions and people send links and just getting into those sort of less formal discussion groups, so with a lot more I guess peer to peer sharing, not necessarily from the people around me but people wider afield” (Catriona).

We found that informants also learned through farm visits: *“...and we want to learn more about agroforestry as well so actually, my husband, is going to some farms next week to look more at their agroforestry systems. So yeah farm tours are really valuable ways of learning yeah”* (Alba).

We also found that informants learn from specific experts and other cultures around the world.

FAO element 3: Synergies. Careful design of diversified systems. Building synergies across food systems, supporting production and multiple ecosystem services

“... I’m still trying to learn about my land a little bit and I don’t want to upset the natural stuff...we’ve got like tons of wildflowers, and they talk about biodiversity, we’ve got so much stuff that I don’t want to try and fix something and then destroy something else” (Catriona).

We found that informants achieve synergies by carefully planning the diversification of their systems. The main characteristics of this process of planning were:

- Diversification of production
- Observation
- Experimentation
- Time
- Space

Informants stated how they carefully select farming practices: *“So we aren’t cultivating the soil at all in order to stop releasing carbon every time it’s turned and to preserve the soil structure for the microorganisms and fungal life, [...] so that’s one of our main practices really is being no dig”* (Alba). Alba also explained how they support and encourage natural processes: *“So we do a lot to try and encourage pollinators and other insects, having areas where insects can overwinter, not just for the benefit of having more insects around but also it helps with pests if we’ve had places where predatory insects can overwinter”*.

FAO element 4: Efficiency. Resource-use efficiency by managing diversity to create synergies between different system components.

“The yields again as a result... largely as a result of not having the weed pressure. But since changing to a full organic deep compost mulch no till system yeah the yields are so much greater. [...] and I guess it’s the amount of saved time from...labour wise required to carry out any weeding or...yeah and also helping to create a really efficient harvest” (Mackay).

Efficient use of resources was critical for interviewees to reduce costs and increase economic efficacy. It was also very important to achieve ecological efficiency through the creation of synergies, as they mentioned:

“I want to run an economically viable agricultural business, but I also want this land to be in the best condition possible, it’s like the trees that I’m planting they’re going to be such a benefit [...] [it] is going to become a lot easier and more productive because of the trees” (Catriona).

“We have areas that are ungrazed and this seems to be very beneficial to the general invertebrate population but especially the bees and we do kind of manage things to be bee friendly and we’ve got bees buzzing all around and of course because we’ve got an invertebrate population and because we’ve got habitats for birds we have a very successful breeding of mainly the sort of common or garden birds and so I would say it’s been successful “ (Erskine).

They also recognised the potential autonomy that efficiency brings to their farming system as a result of diversity and synergies:

“I definitely think the autonomy is a really important one and again that comes back to what I was saying about siloed rural payments and all of that sort of stuff...” (Paisley).

FAO element 5: Recycling. Waste is a human concept – it does not exist in natural ecosystems.

“ we compost everything, nothing really leaves the site, we generate very little rubbish. [...] all of our biodegradable waste is composted and used within the garden and within the beds where we’re growing our plants and everything. [...] some of the waste gets passed on, well it’s not waste as such but some of the botanicals get passed onto other businesses for use further down, so we pass some of them onto jam makers who use some of the berries that we use...” (Paisley).

The interviews showed that informants have recycling practices to different degrees, from recycling waste to circular systems where everything was seen as part of the process with minimum creation of rubbish. Some informants mentioned the need to reinforce this area within their farming system and others also mentioned repairs as part of their recycling models.

Recycling compost and manure was the most common practice amongst informants:

“...because a lot of the compost that we’ve used so far is bought in from like the household waste recycling centres which I think is fine because it’s like a waste product and it’s still local but it would be better if we could make our own”(Alba).

Informants also included non-organic material as part of their recycling practices such as fixing things rather than throwing them away and buying new things or creatively use kit and equipment for multiple functions.

For others circular systems were very important: *“There’s obviously no food waste, any sort of raw*

vegetable waste gets fed to the animals, like scraps of stuff during harvest that's come off the market garden. Everything else then gets composted. We actually are a site for tree surgeons in Edinburgh who come and drop all of their woodchip waste here which again we turn into more compost. [...] it's a fairly circular system on the farm" (Mackay).

FAO element 6: Resilience. Diversified agroecological systems are more resilient – they have a greater capacity to recover from disturbances.

"the resilience to climate change, the resilience in terms of business, like financial resilience, building that community of people who want to buy meat from us and having that support I think is really important. Yeah definitely!" (Isla).

When we asked informants about resilience, they talked about it from different perspectives. Informants talked about resilience in terms of:

- Most informants were creating environmental resilience through diversification or increasing ecological functions:

"...in terms of climate change its more resilient I think because we're actively trying to store more carbon in the soil rather than release it"(Alba).

"...just by increasing the biodiversity in and of itself that creates resilience, that's what biodiversity does" (Paisley).

"... if we create as diverse as possible system then it gives us the greater resilience both to market pressures and from a supply and demand point of view but also [...] plants or animals not being particularly successful over certain periods of time"(Mackay).

- Informants also recognised the economic resilience of implementing these practices by reducing dependence on external inputs:

"I guess with the cover crops some farmers might...especially conventional farmers would look at it and think you're crazy not being able to yield something off an area of land for a specific period of time when you're using it as a cover crop. But ultimately it pays for itself severalfold when you don't have to pay for fertiliser and your yields will be way up the following year"(Mackay).

In addition to creating economic, ecological, and social resilience, for some informants it was about creating strength for an uncertain future.

"it was also from the understanding that we were approaching a climate crisis so [...] it was also about creating resilience for our own family and having the opportunity to actually grow our own food and having that space to support ourselves when the time came... As it turns out it's happened [...] it is here so we thought that perhaps it wouldn't happen within our lifetime but maybe within our children's lifetime but yeah it's kind of...it's here and it's now so that's the reason our farm is high up" (Paisley).

Social and cultural context of agroecology in Scotland

FAO element 7: Human and Social Values. Agroecology places a strong emphasis on human and social values, such as dignity, equity, inclusion and justice all contributing to the improved livelihoods dimension of the UN Sustainable Development Goals.

***“... me and my wife we’re on our early 30s so we’re from a different generation so my wife is probably better at certain farming jobs than I am and I’m better at certain farming jobs than she is but we take it in our stride and I don’t see any issue why women shouldn’t be allowed to farm”
(Dylan).***

We discussed with informants three main ideas of this agroecological element: gender equality; youth and farming; and how they think the public perceive them.

Regarding gender inequalities informants did not find any difference. The interviewees in this project were women (7 out of 10) and they did not mention any difficulty in doing their work.

Regarding young people entering farming, informants mentioned that it is not that difficult to find work as a farm labourer, but to become a farmer as new entrant it is almost impossible for new generations.

Informants mentioned as main barriers:

- Access to land and the security needed to build ecological resilience: *“if you want to be a farmer and have your own farm, access to land is just the biggest most difficult barrier to overcome”*(Alba).
“partly because of the difficulty of accessing land [...] ultimately it’s very difficult to turn a profit, or make farming systems viable [...], you need longer term insight and investment to actually make it stack up and when you don’t have I guess security over the land, or you’re having to rent [...]it’s very difficult to create...with confidence to be able to go into a system and put the infrastructure in place that’s going to back your business or make a return for your business”(Mackay).
- High land prices
- Training in agroecological farming systems
- Access to subsidies for small scale farming

“I would say, probably also training as well I would say. There is nowhere really you can go to train in this style of farming that we do, that’s why it’s so common to have interns or apprentices to learn on the farm and I guess the subsidy system as well has to be playing a role in some way that you...if you’re a small scale you won’t get some of the support that you would get at a bigger scale. I think supermarkets have a lot to answer for to be honest”(Alba).

The third main idea we discussed as part of this element was about how they thought the community perceived them. It was interesting to find that farmers felt there was a lack of fair treatment from the public but also from other farmers within the community who were using different farming systems.

Informants expressed that they encounter:

- Frustration. *“I find it really frustrating because this system of crofting seems to be perfect for future food production, for strengthening the rural communities, for so many things that everybody says they want but then instead we get told well you’re not productive [...] and we’ll put more money into producing wildflower meadows down south. So it’s really frustrating [...] and we’re in tourism and tourism hotspots and holiday homes and stuff it’s impossible to get a new croft because the croft that should be worth about £10,000 or £15,000 is worth £100,000 because somebody can put a holiday house and a bunch of holiday pods on it”*(Catriona).
- Farmers and crofters are put under a lot of pressure and treated unfairly. *“I think it’s really hard because farmers are being expected to carry a multiple burden of climate change, human health and biodiversity loss crises and it’s being put at our door by the fossil fuel lobby insidiously. ...So I think it’s really difficult for farmers because we’re being put...the spotlight is being put on us as being responsible for these three challenges. So yeah I think that that’s really difficult and I think that sometimes we feel the need to articulate and justify our existence and justify what we’re doing and that’s hard”*(Isla).
- Lack of understanding. *“I don’t think they understand what it is and its not just the general public, I don’t think a lot of the agricultural organisations, a lot of the Research Institutes and a lot of the politicians understand crofting at all. We get lumped into boxes with people who’ve got hundreds of acres of arable land or thousands of acres of arable land and expected to fit in with those systems”*(Catriona).
- Divides within the farming-crofting community. *“It’s also within agriculture so the public looking it can be quite negative about...and broad-brush all farmers in the same way and that is difficult because not all farmers are the same and then within farming there are these splits between who’s farming in different ways and what...different expectations, so we’ve kind of got infighting as well as challenges from out with our sector. So, I think it’s a pretty difficult time”*(Isla).

FAO element 8: Culture and food traditions. Agriculture and food are core components of human heritage. Hence, culture and food traditions play a central role in society and in shaping human behaviour. However, in many instances, our current food systems have created a disconnection between food habits and culture.

“we sell our beef direct in beef boxes and so I think that cultural aspect is really important because you can tell a bit of that story to your customers, and they much more appreciate” (Isla).

When we talked about food and farming, for most of the informants, farming was about local food production. It was a priority to produce locally or even the reason why they started farming.

“...our main interest was because we realised that there’s a crisis in the food system and we wanted to try and work out a way of producing food in a way that can create a more food secure system but also one that works alongside nature in a sustainable way and I guess those are our...the third point was we wanted to try and create a future for the farm here itself, so a combination of those three things yeah led us to want to begin farming...”(Mackay).

“...almost a political thing first because studied [...] at university and just learnt a lot about the many problems of our current food system and I wanted to work towards making it more sustainable and healthy [...]. So I worked for a bit in community food growing projects in London and I started doing a PhD actually as well at the Centre for Agroecology Water and Resilience [...] I wanted to help in the movement for a better food system and basically in the end [...] I wanted to be a farmer basically”(Alba).

Most of the farms or crofts in the case studies were shortening the food chain (8 out of 10) by selling their production in local markets or directly to customers. Locally produced food that connected food production with land was important for most of the interviewees. For some of them it was about creating healthier production food, for others it was about rediscovering lost Scottish food cultures, for others it was about the breeds or about educating eating behaviours.

“...I think you know culinary it is good to educate the public about what they can do with food and locally produced food and seasonally produced food and again putting the clock back that’s what people had to do, they had to eat what was available at the time of year and they had to make use of all of an animal and that is a good thing”(Leana).

It was also about rediscovering Scottish food cultures through research, stories and legends:

“...there is a huge amount of Scottish food culture that has been lost around our native plants [...] I’m researching all of them [...] it comes from enclosure, loss of enclosure, it comes from removal of people off the land, so the clearances, it comes from over regulation of the whisky industry which actually removed ingredients that were historically used in our spirits. [...] as well so removal of all the monasteries. It’s colluded to hide and to eradicate lots of the culture around our own native plants and we do a lot of work to research and to try and rediscover that culture. We are actively [...] compiling lists of stories and legends and culinary uses of our native plants as we go along and we use that in our marketing [...] but it’s also part of what we try and promote not just for our own business but for other businesses that potentially can use it and to create a really vibrant food culture for Scotland which we have absolutely lost touch with”(Paisley).

“ the Scottish identity, the Scottish culinary identity is arguably stronger than the rest of Britain’s culinary identity which is weak. [...] no we don’t do fish ‘n’ chips, we do haggis. So...I don’t think there is a [...] culinary identity in Scotland to be upheld [...]. I think what we have got we’ve got it all going for us as...to create a food producing and culinary approach which will become a tradition that is good, clean and fair quoting the Slow Food mantra. So Scottish farmers can produce a green, clean product and they’ve got it all to go for. Agroecology is eminently scalable, Scotland could become the agroecological leader, global leader and it’s so easy and possible. So we can actually create a tradition in good, clean and fair which can include haggis [...]”(Ailsa).

Enabling environment for agroecological systems in Scotland

FAO element 9: Responsible governance. Agroecology calls for responsible and effective governance to support the transition to sustainable food and agricultural systems.

“... the priority is to support farm habitat infrastructure [...] to have agroecological grant support for agroforestry and that is going to mean clear incentives that are uncomplicated for farmers to transition to an agroecological farming system and it is a scalable system. At the moment they think that its small scale and they think food production from farms like we’re doing, on farm processing, its small scale it’s not. It has to be scalable; it can be scalable and we need clear incentives to support what we’re doing...” (Ailsa).

We asked farmers and crofters if they felt able to take charge of the decisions that affect them. In addition, interviewees talked about different governance structures which restrict or allowed them to do what best for the type of farming system they have. The results showed that most of farmers-crofters did not feel to be able to take charge of the decisions that affected them. Size of the farm was commonly mentioned by interviewees, due to lack of recognition of the economic, social and environmental importance of small-scale farming systems and disadvantages because of the lack of access to support for managing their land. Informants referred to different types of support: economic, social recognition, enabling small businesses to work through taxation systems, customers paying farmers realistic prices for producing food without subsidies.

“...let’s get rid of subsidy and actually just charge people what it costs to produce food” “I think there are real challenges about how holistic decision making and holistic planning which is really adaptive you’re being asked to make decisions [...] for things that might not be able to happen later in the year because actually there’s horrendous weather and things change” (Isla).

Also, larger farms felt disadvantaged because of the lack of support for the type of farming system they have. Most informants mentioned the need for more holistic, adapted, and supportive economic incentives.

“Well it’s a complete revision of agricultural support [...] it’s going to be a hard fight but it’s going to involve building a support system that actually acknowledges the social and economic and environmental importance of small scale production in remote areas” (Erskine).

“...If you compare the amount of resources at play in bigger farms and smaller farms we could really benefit from the help but we’re sort of excluded just because we’re thought of as too small to have any impact but I think we are making a big impact on our community”(Alba).

“...it takes more effort to run a small farm than to run a big farm because of the scale of it. It’s much easier to create different income streams or to create different ventures on a much larger piece of land than it is on a small piece of land so...the more landing holding you have the more subsidies you get. Actually it should be completely the other way around. The more land you have the less subsidies you should get” (Paisley).

Interviewees also mentioned the economic relations between farmers and supermarkets in relation to the choices farmers have to implement their preferred practices: *“An easy one would just be more support for smaller scale farmers. I think we should try and offer farmers...there should be some thought, some real thought gone into how to lessen the control of the supermarkets because I think farmers would have more choice, I think there are lots of farmers would want to do better practices but don’t feel like they can because they have to maximise their yield and they have a lot of debt, they’re under a lot of pressure”.*

FAO element 10: Circular and solidarity economy. Agroecology seeks to reconnect producers and consumers through a circular and solidarity economy that prioritizes local markets and supports local economic development by creating virtuous cycles.

“...So...there is obviously a deeper connection if your farmer actually feeds you”(Alba).

“I think things like that really help connect people with the land because they’re realising that you can’t just have whatever you want all the time and the joy that comes from the first tomatoes is just incredible”(Isla).

Regarding circular and solidarity economy, we found, as mentioned previously, that 8 out of 10 interviewees were shortening the food chain by selling their products locally. We also found that they were innovating in the way they sell their products using online selling, advertising and social media or using local networks and cooperation with other farmers.

We also found that for some of the informants, participation of costumers or communities in the farming system was part of their model.

“... I think that crofting it’s as much a social system as an agricultural system and it’s about having families occupying this land ...”(Erskine).

“...we havemembers... We know each other because we see each other every week and we chat about what’s in the veg bags and what’s going well and what they’d like to see more of next year you know? It’s very different to like a big farmers relationship I think”(Alba).

All of them acknowledged the importance of selling locally at large or small scale and in a few cases interviewees mentioned the premium price, but for a few others it was important to produce food at affordable prices.

“it’s a system that crofting fits in perfectly with... because crofting is organised in townships of usually between 6 and 15 people, or 6 or 15 families. So each one of us is too small to like make an impact on things. I couldn’t start my own local food hub but if I work with my neighbour and a bunch of other people then suddenly we’ve got enough produce that it’s worth selling, it’s worth us delivering to people”(Catriona).

“it’s more fulfilling job if there are more people around and people are so disconnected from where their food comes from and just the natural world in general. It’s...I’d rather have more farmers and better food than sort of fewer farmers and food that’s devoid of nutrients depleting the soils and really cheap but actually we’ve paid the true cost of that food elsewhere in the system through the NHS, through polluted rivers, all that kind of stuff. This food is more accurately priced yeah”(Alba).

Discussion

This project is, to our knowledge, the first semi-quantitative analysis of the use of agroecological principles and practices in Scottish agriculture. The online survey (192 respondents) and in-depth interviews (ten informants) reflected the composition of Scotland’s agricultural community in some

characteristics (age structure, gender [although interviewees were predominantly female], land tenure) but not others (capturing a greater proportion of organic farmers than overall in Scotland). Respondents represented the range of farming enterprise categories in Scotland, although the interviews did not capture dairy farms or farms producing intensive cash/combinable crops. As participation in the survey and interviews was voluntary, respondents formed a self-selecting group which often causes unequal representation.

Characteristics of agroecological systems in Scotland

Agroecological practices used in Scottish farming systems predominantly involved **recycling** and **efficient use of natural resources** (by managing soil tillage, nutrient inputs and drainage). Practices underpinning **diversity** were used frequently by interviewees, who recognised the benefits of diversifying for resource-use efficiency and were moderately common amongst survey respondents. Amongst survey respondents, evidence was more variable of practices being used to promote **resilience** to pests and diseases and **synergies**, although some respondents used monitoring and cultural control of pests and diseases and aimed to increase livestock foraging (including mob grazing) and reduce feed inputs. Greater attention seemed to be paid to creating synergies by small-scale farmers who were interviewed. Interview informants also mentioned that the flexibility of their farming approach meant they could be adaptable, creating economic resilience, while selling products locally encouraged interest in food production and community resilience.

Co-creation and knowledge sharing was widespread amongst survey respondents and interviewees, many of whom acquired new knowledge about farming practices through their own experimentation and research, and by consulting others locally and further afield. There was some evidence of gender differences in the use of paid advisory services amongst survey respondents, although this was not apparent amongst interviewees (who were primarily female and represented agroecologically managed systems). The importance of peer-to-peer learning and farm visits came through strongly in the case study interviews, likely reflecting the knowledge-intensive process of agroecological farming.

These findings indicate that while some agroecological practices are widely used in agroecological and conventional farming systems, some practices are used infrequently, which might be due to limitations in their applicability to Scottish farming, or quality constraints imposed by downstream value chains (e.g., zero tolerance of pests and diseases), or lack of familiarity amongst farmers and their networks. Peer learning and on-farm demonstrations were key in supporting land managers in their own experimentation.

Recommendations: Greater understanding is needed in Scotland of the constraints to using agroecological practices in different farming sectors, and whether barriers to uptake result from lack of technical know-how, pedoclimatic conditions or value chain requirements. Barriers might be overcome, at least in part, with evidence to demonstrate agroecological outcomes, tapping into the knowledge sharing infrastructure and mechanisms that are already being used by many farmers and crofters.

Social and cultural context of agroecology in Scotland

New farming entrants featured more strongly in adopting agroecological farming approaches compared with survey respondents from families with more than one generation in farming. The primary motivations were to improve soil health and biodiversity and reduce inputs, and those practicing agroecological approaches were more likely to record that they had achieved these desired

outcomes, although this might simply indicate that those practising agroecology are more likely to monitor outcomes. Most respondents felt their farm resilience was improved by practices they used to improve soil health and biodiversity, but fewer linked this with improved financial strength of the farming business. These findings indicate that for **improved rural livelihoods** to be achieved with agroecological approaches in Scotland, more evidence is needed to link farming practices with economic, social and environmental outcomes, accompanied by indicators or metrics that can be readily used by farmers to monitor their own systems. Interview informants expressed concerns about lack of value by the wider public of their farming efforts but were encouraged by the opportunities for collaboration and cooperative working between food producers. Many survey respondents supported statements regarding the need to diversify food systems and reconnect consumers with local/traditional food habits, indicating a willingness to consider the human and social values attached to food production and support **cultural values around diet and food consumption**. Interview informants found it important to create a community around their products and connect with consumers.

Recommendations: We found that survey respondents and (particularly) interviewees were often aware of the social and cultural considerations of sustainable food systems, but there was less knowledge amongst survey respondents around how these could strengthen rural livelihoods. This could indicate their implementation is at a relatively immature stage in Scotland, which might result from the scales and levels at which they are typically practiced. If large-scale behavioural change in food systems depends on ‘shock’ events, as suggested by the literature, then consideration will need to be given to the appropriate triggers for transformational change, for example in achieving the goals of the Good Food Nation (Scotland) Bill (2021).

Enabling environment for agroecological systems in Scotland

Many respondents supported statements about minimising the environmental impact and carbon footprint of food production and the need for sustainable farming methods to secure the future of Scottish farming, highlighting a willingness to support and adhere to **responsible governance** measures. Interview informants highlighted governance issues that constrain more extensive efforts to farm agroecologically, such as lack of community decision-making powers, difficulties in purchasing land, and food prices not reflecting the cost of production. Suggestions to encourage agroecological transitions included compensating farmers for making a transition, improved access to capital for infrastructure costs, and more equal support for small scale as well as large scale farmers. Half of the survey respondents had not participated in any environmental incentive/subsidy scheme, irrespective of their farming approach, which could indicate that many farming practices classed as agroecological are not clearly defined and do not lend themselves to current incentive schemes, or it might indicate a lack of willingness to participate in payment schemes (this point was made in interviews). Many agroecological farmers are small scale and might disproportionately suffer from a lack of access to incentives, despite delivering to environmental policy targets, or see incentive schemes as contrary to their farming ethos. Respondents largely supported statements about reconnecting producers and consumers and creating resilience in food production by increasing the diversity of people involved, which underpins the **circular and solidarity economy**.

Recommendations: We found that while many recent UK/Scottish government strategies have been designed to support production systems that limit the environmental impact of agriculture and improve social and food justice, the current incentive schemes might constrain some farmers in

working towards these goals or might not be appropriate for agroecological farming. This could simply represent a time lag, however, as post-CAP incentive schemes are still under discussion for Scotland. Further work is needed to examine the financial and non-financial incentives that would deliver the best enabling environment for agroecological farming in Scotland.

Understanding of agroecology in Scottish farming

Survey responses showed a lack of clarity over the meaning of agroecology or how to implement it – even amongst some respondents who classed their farming approach as agroecological. This suggests that **understanding of agroecology** as an approach or paradigm is not clear to everyone. If agroecology is to be implemented widely, farmers and crofters need to know more about agroecology as a paradigm and the associated economic, social and environmental outcomes.

Despite lack of familiarity with the terminology around agroecological approaches, many respondents were already implementing agroecological practices, largely without financial subsidies, even if they were not adopting all aspects of the agroecological ethos. This indicates that agroecology provides a broad and inclusive pathway to sustainability in agriculture, albeit one that might fall between current incentive schemes.

Many survey respondents thought that agroecology has the potential to deliver benefits for food production, enhanced environmental outcomes, and improved resilience to external shocks, indicating the potential role for agroecology in addressing the current biodiversity and climate crises. Similarly, many respondents were supportive of statements about improvements in agronomic, economic and social features of agriculture that reflect features of agroecological systems, indicating they were open-minded about the ways in which farming and food systems could be changed.

Recommendations: Mechanisms are needed that enable those already practicing agroecology principles to flourish, and to support newcomers to develop and apply these skills, at different scales (from very small to large holdings). Many land managers are already using agroecological practices and their contribution could be better recognised. Greater understanding is needed, however, about the financial and social, as well as the environmental, outcomes of agroecological approaches: agroecological farming is more knowledge intensive, and less reliant on chemical fixes, than conventional modern farming and demands better understanding of ecological processes, so the benefits of this approach need to be clear to encourage adoption. Widespread availability of training, advice and knowledge-sharing mechanisms could support agricultural transitions, taking account of different ways that new information is acquired by different demographics in the farming population.

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