Exploring Agroecology in Scotland with Critical Systems Heuristics

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Declaration

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Three chapters of this thesis were conjoint work with Professor Alec Morton (AM) and Shona Blair (SB). My contributions and those of my co-authors are outlined in Table 1.

Table 1. Conjoint work contributions.

Chapter	**Thesis Author**	**Co-authors**
2	• Designed the study • Conducted the interviews and analysis • Drafted the manuscript and led the journal peer review process	• AM and SB supervised the study • AM and SB reviewed the draft manuscript and provided feedback throughout the peer review process
3	• Conducted the review • Drafted the manuscript and led the journal editorial review process	• AM and SB reviewed the draft manuscript
4	• Designed the study • Conducted the interviews and analysis • Drafted the manuscript and led the journal peer review process	• AM and SB supervised the study • AM and SB reviewed the draft manuscript and provided feedback throughout the peer review process

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Abstract

This thesis aims to demonstrate the utility of critical systems heuristics (CSH) for exploring perspectives on agroecological transition in Scotland. Agroecology is of growing interest in Scotland, but there is presently a lack of understanding of the role it might play in a sustainable farming transition. Additionally, current research suggests that it is a concept with which farmers in Scotland are unfamiliar. This thesis reports an application of CSH to explore perspectives on agroecological transition in Scotland to address this knowledge gap. The research derives a series of practical recommendations for the progression of agroecological transition in Scotland, namely: support for a greater diversity of farming systems; action across the entire food system to avoid "lock-ins"; improved tools to measure farming outcomes; and nuanced and precise conversations regarding the nature and purpose of agroecological farming. Furthermore, a preliminary phenomenological exploration of agroecology in Scotland not only finds that agroecology is an approach with which some farmers are familiar, but also characterises it as a value-driven approach to developing individualised, lower input farming systems.

A further aim of this research is to consider the utility of CSH for exploring problems of agricultural transition. The thesis reports a second, workshop-based application of CSH that explores data quality for an agricultural software organisation aiming to accelerate a transition to data-driven farm management decision-making in the UK. The workshop surfaced key areas for improvement in the organisation's data processing and ingestion practices. Changes were implemented over a period of three months that helped the organisation move towards their data quality objectives by reducing processing time and improving data accuracy. The thesis compares both of the reported CSH applications to understand the merits of the framework for exploring problems involving farming change. Methodological contributions include two distinct, accessible applications of CSH that I hope may lower the barrier to adoption of the method for systems researchers and practitioners. Further, positing that the under-utilisation of CSH relative to soft systems approaches is at least in part a result of a lack of clarity surrounding the method, the thesis includes a review of the CSH literature to understand how the framework has been applied and provide clarity on key terminologies.

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List of Abbreviations

CSH	Critical Systems Heuristics
SSM	Soft Systems Methodology
AET	Agroecological Transition
CIDSE	Coopération Internationale pour le Développement et la Solidarité
CSA	Community Supported Agriculture
LWA	Landworkers' Alliance
IFM	Integrated Farm Management
SI	Sustainable Intensification
ESR	Efficiency Substitution Redesign
FSR	Farm System Research
TPCA	Trans Positional Cognition Approach
PT	Participant Theme
Ri-PT	Researcher Interpreted Participant Theme
AMP	Adaptive Multi-Paddock Grazing
MSO	Maximum Sustainable Output
GHG	Greenhouse Gas
ERP	Enterprise Resource Planning
CSD	Critical Systems Discourse
HSS	Home Saved Seed

Chapter 1. Introduction

1.1. Overview

This chapter first describes my personal motivation for beginning this research project, outlining where my interest in agroecological farming transitions originated. An academic rationale for the research is then provided. This considers why agroecology is a relevant concept in the context of Scottish agriculture and provides a justification for its exploration using critical systems heuristics (CSH), which – despite its substantial contributions to the systems thinking tradition – has not been widely utilised compared with alternative soft management science methods, such as soft systems methodology (SSM) and cognitive mapping. The chapter then outlines the research aims, the specific research questions, the contributions of this research, and an overview of the thesis structure.

1.2. Research Background

Farming plays a significant role in the present climate and biodiversity crises. Recent years have seen growing interest in nature friendly farming to mitigate agriculture's contributions to these issues. This is an approach to farming that aims to support natural ecosystems while fulfilling its core function of food production. It is this issue that first engaged me with sustainable agriculture. Can farming really utilise ecological symbioses to transition away from harmful conventional farming practices?

"Regenerative agriculture" in particular is a term that is increasingly used in discussions of sustainable transitions in agriculture. Explained simply as five principles – minimise soil disturbance, cover the soil surface, crop diversity, living roots in the soil, and livestock integration – regenerative agriculture intrigued me as alternative approach to farming that appeared to deviate significantly from the practices followed on the farm where I grew up. If regenerative agriculture was indeed superior both environmentally and economically for farmers, why is it not an approach that has been more widely adopted in Scottish agriculture? Do the principles work in practice? Engaging with the academic literature revealed that, while regenerative agriculture is a term now commonly used, the theory and practice on which it is based belongs to the field of *agroecology*. I was therefore interested to explore whether agroecology worked in practice in the Scottish farming context.

My background is in science and data, and so my initial leaning was to find a way of exploring this problem objectively with quantitative data. However, farming is an industry that is lagging in its use of quantitative data to drive decision-making at the farm-level. Further, after drilling deeper into the issue of sustainable farming transitions, it appeared to me that clarity was required about what "sustainable" farming means and looks like in practice, given the diverging perspectives that exist on farming change. Management science offers several soft methods for use in such contexts, and I became interest in exploring how these methods might help further our understanding of agroecology in practice.

1.3. Academic Rationale

1.3.1. Problems with Modern Agriculture

There is mounting concern over the sustainability of our food and farming systems. Last century's Green Revolution saw unprecedented increases in crop yields, owing to technological revolutions in synthetic fertilisers and pest controls, plant science, and machinery. However, this sharp increase in productivity has come at a cost: agriculture is a leading contributor to greenhouse gas emissions and biodiversity loss, and diet-related non-communicable diseases are on the rise (United Nations Environment Programme, 2023; Willett et al., 2019). Norman Borlaug's contributions to the Green Revolution earned him the 1970 Nobel Peace Prize as a result of the immense impact these innovations had on global food security, and yet over 800 million people globally are still without sufficient food (Willett et al., 2019). Since then, interest in alternative approaches to agriculture has grown in both developed and developing countries.

In many developing countries – despite the dramatic yield increases brought about by technological innovations – equity, stability and sustainability of food production remained key challenges, particularly in Africa (Conway & Barbier, 1988). Green Revolution technology adoption failed among many farmers due to both socioeconomic and biophysical barriers, meaning that alternative approaches were required to move forward agricultural development (Simmonds, 1986).

In developed countries – who benefitted greatly from last century's technological innovations – interest in alternative approaches to agriculture is largely due to concerns over the environmental impacts of our modern food and farming systems (M. A. Altieri & Rosset, 1996). In the UK, agriculture contributes 48% of total methane emissions, 69% of total nitrous

oxide emissions, and 2% of total carbon dioxide emissions (UK Government, 2022). There is also major concern about the impact of conventional farming practices on biodiversity levels, with UK farmland bird species having declined 58% since 1970 (State of Nature Partnership, 2023). These concerns have led to the advocacy of systems that aim to protect and, as far as possible, work with nature to produce food.

1.3.2. Agroecology as an Alternative Approach to Agriculture

Agroecology is an alternative approach to conventional agriculture. At a farm level, it emphasises the enhancement of beneficial ecological relations to reduce dependence on external inputs. More broadly, agroecology aspires to transformation of our food system.

> Agroecology is a way of redesigning food systems, from the farm to the table, with a goal of achieving ecological, economic, and social sustainability. Through transdisciplinary, participatory, and change-oriented research and action, agroecology links together science, practice, and movements focused on social change (Gliessman, 2016).

Until the 1970s, agroecology was largely considered only as a science – the study of ecology applied to agriculture for the design of productive food systems (Wezel et al., 2009). This evolved a practical dimension, the core focus of which was to shift farming away from monoculture, high input systems, towards diverse, resilient systems built around beneficial ecological relations (M. A. Altieri & Rosset, 1996). Agroecology has since also manifested as a social movement that strives for just food systems and food sovereignty (Holt-Giménez & Altieri, 2013; Sélingué, 2007). Food sovereignty, refers to the right of regions and communities to design and control their own food systems.

Agroecologists emphasise the importance of principles to inform practices – explicit acknowledgement of the different environments and circumstances of individual farmers is central to the design of agroecological systems. Altieri (1996) proposed an initial set of five ecological principles to be integrated into farm management: increase soil and above ground biodiversity; increase biomass production and soil organic matter; reduce use of synthetic pest controls, and nutrient and water loss; build functional relationships between plants and animals; and optimise cropping design for efficient use of resources (M. A. Altieri & Rosset, 1996).

Agroecology has now broadened, and conceptualisations may also include social, economic, and political dimensions. This is reflected in several recent sets of principles (CIDSE, 2018;

Dumont, Vanloqueren, Stassart, & Baret, 2016; FAO, 2018; Wezel et al., 2020). These principles inform locally adapted practices, which are intended to benefit the agroecosystem, or indeed the food system, depending on the level of application.

1.3.3. Defining Agroecology: A Principle Based Approach

If agroecology is to influence a farming strategy that can address the environmental crises, it is crucial that we are clear on how the approach is defined. Agroecology was originally considered primarily as a scientific discipline, but since the mid 20th century it has grown new practical, social, and political dimensions (Anderson, Bruil, Chappell, Kiss, & Pimbert, 2019; Wezel et al., 2009). This means that a rigid definition of ecology applied to agronomy is no longer satisfactory – agroecology may instead now be considered a holistic approach to food system redesign (Francis et al., 2003; Gliessman, 2016).

"The ecology of food systems" (Francis et al., 2003), however, is perhaps too broad a definition to be meaningfully applied in practice. As such, modern definitions of agroecology are primarily centred around sets of agroecological principles. Emphasis on agroecological principles in part stems from the growth of agroecology as a concept (Wezel et al., 2020). Agroecology is no longer solely an ecological concept, and so agroecological farming practices (Table 2) alone are not sufficient identifiers. Further, any given farming practice cannot be considered exclusively agroecological, since it may also be widely adopted in other farming systems (Tittonell, 2020).

Emphasis on principles also in part stems from calls for a paradigm shift in agricultural research (Bawden, 1991; Pretty, 1994). Increased recognition of the detrimental impacts of modern farming and food systems has resulted in a critique of the reductionist paradigm that has dominated since last century's Green Revolution (Douthwaite, Kuby, van de Fliert, & Schulz, 2003; Pretty, 1995). The prevailing view among agroecologists is that the implementation of rigid sets of practices and adoption of new technological innovations is not sufficient to deliver sustainable and just food systems – this must instead be achieved through the application of principles and system redesign (Nicholls, Altieri, & Vazquez, 2016; Wezel et al., 2020).

Moreover, adopting a principle-based approach allows for the emergence of novel agroecological practices. Principles inform practices (Dumont, Wartenberg, & Baret, 2021; Nicholls et al., 2016), and so clearly defined principles can allow for the investigation of agroecological systems without the need to a priori specify a set of practices. This is important

in the context of developing sustainable agricultural systems, as the adoption of overly-prescriptive innovation in this context is demonstrably poor (Pretty, 1995; Simmonds, 1986).

Table 2. Agroecological farm management practices with their corresponding agroecosystem functions. Collated from Nicholls and co-authors (2016) and Hawes and co-authors (2021).

Management Practice	**Function**
Agroforestry	Enhancing soil biology, increasing biodiversity and agroecosystem resilience, and carbon sequestration.
Animal integration	Nutrient recycling and enhancing soil organic matter.
Compost	Primarily a means of introducing organic matter into the soil.
Cover crops and green manures	Source of organic matter and soil nutrients.
Crop rotation	Manage soil nutrients, weeds, and disease.
Insectary flowers	Enhance pollinator populations.
Intercropping	Increase yield and yield stability, and nitrogen fixation.
Living fences	Enhance biodiversity and agroecosystem resilience.
Microbial pesticides	Environmentally benign alternatives to chemical pesticides.
Mulching	Recycles biomass back into the soil, increasing organic matter and enhancing soil biology.

Key sets of agroecological principles have been defined by Nicholls and co-authors (2016), Dumont and co-authors (2016), Wezel and co-authors (2020), the CIDSE (2018), and the FAO (2018). Each proposed set of principles represents the ecological, practical, and socioeconomic dimensions of agroecology to different extents, and each with varying degrees of specificity. Moreover, the principles have relevance to greater or lesser extents at the farm level. Some are

clearly intended to inform farm management practice, while others have implications for the entire food system.

The principles outlined by Nicholls and co-authors (2016), based on the work of Altieri and Rosset (1996), consider exclusively the ecological dimension of agroecology. They are therefore directly relevant to farm management and the focus is at the agroecosystem level as opposed to the food system level. The principles inform a diverse range of practices, and the implementation of these practices drives ecological processes for agroecosystem function (Figure 1). The emphasis on site-specific solutions arises from distinct ecological relations present in any given region or any given farm. As such, the adoption of generic solutions or technologies is not suitable – they must instead be tailored to the local environment (Nicholls et al., 2016).

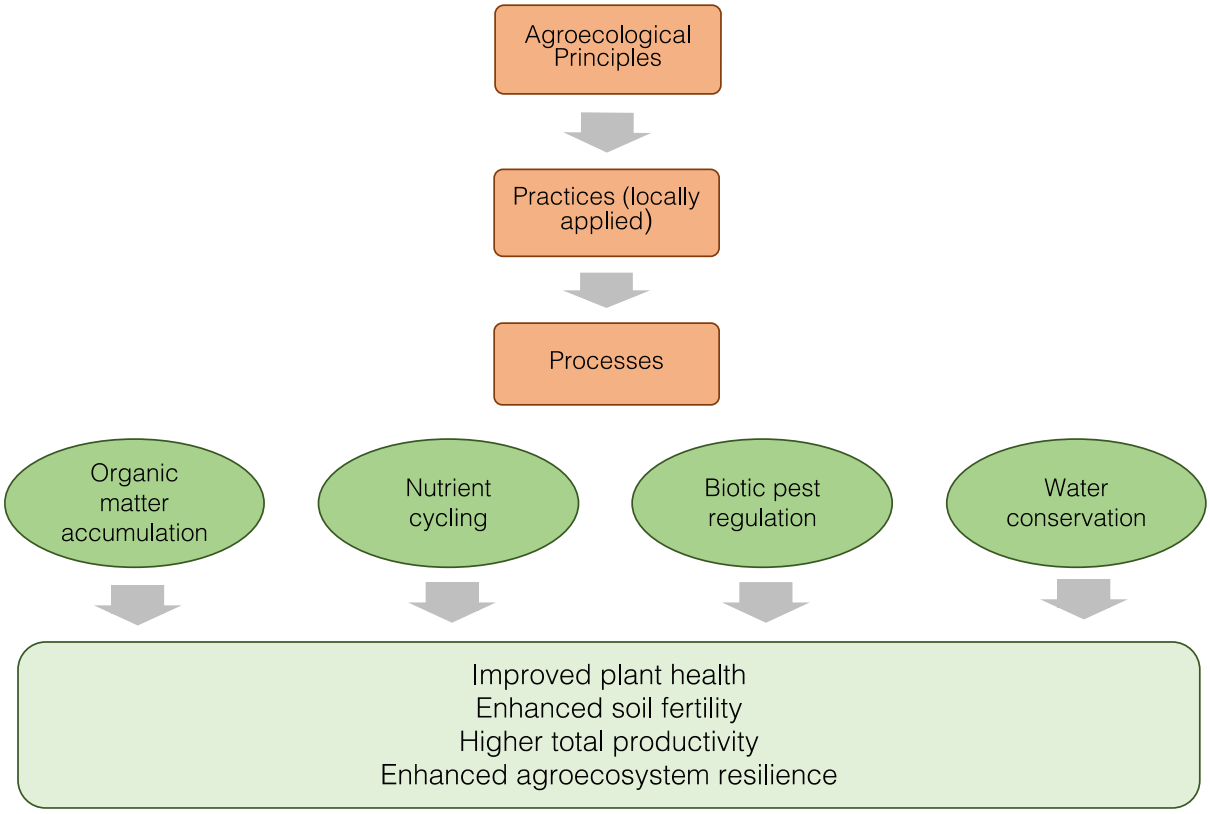

Figure 1. Process of agroecological transition. Following Nicholls and co-authors (2016).

According to Nicholls and co-authors (Nicholls et al., 2016), one of the aims of well-managed agroecosystems is pest regulation i.e. reduce insect pests, diseases, and weeds. A second key aim is yield stability. Techniques such as intercropping result in less frequent crop failures when compared with monocultures among small farmers in developing countries (Nicholls et

al., 2016). Agroecology works towards these aims by focussing on the root causes of problems, as opposed to treating symptoms.

> Agroecologists regard pest problems or nutrient deficiencies as a symptom of a failure of an ecological process (biological control or nutrient cycling) and thus endeavor to find out the root causes of such unbalance. Instead of focusing on one particular component of the agroecosystem, Agroecology emphasises the interrelatedness of all agroecosystem components and the complex dynamics of ecological processes. Thus Agroecology is an alternative approach that transcends the use of alternative inputs to develop integrated agroecosystems that do not depend on external, off-farm inputs (Nicholls et al., 2016).

These principles are agroecosystem-centric, and it is evident that these could influence change at the farm level. However, it is less clear how implementation of these principles could lead to food system redesign. Ecological principles are most relevant to farm-level agroecological transitions (AETs), but are these the only principles that are relevant? Or should other dimensions of agroecology also be considered at this level?

Dumont and co-authors developed socioeconomic principles to integrate with ecological principles (Dumont et al., 2016; Dumont et al., 2021), highlighting that social and economic dimensions are now integral to agroecology and cannot be overlooked.

> Fundamental aspects of agroecology, such as its collective capacity-building, and emancipating goals, integration of local and scientific knowledge, territorial dimension, mobilization by multi-actor networks, and links with food sovereignty, might otherwise be neglected (Dumont et al., 2016)

Their outlined set of principles integrate ecological principles with seven additional socioeconomic principles (Dumont et al., 2016), recognising the change and growth that the concept of agroecology has undergone since the 1970s (Wezel et al., 2009). Its relevance and application at not only a farm level, but also a food system level necessitates new dimensions with associated principles that guide just and fair development. Agroecology is no longer simply concerned with the enhancement of on-farm ecological relations, but also wider social and political considerations with respect to food production and consumption.

The integration of socioeconomic principles is not simply to extend agroecology beyond the farm-level to the food system level. Dumont and co-authors' (2021) principles are intended for

application at the farm-level. Good working conditions, social embeddedness, local food systems, co-creation of knowledge, democratic decision-making, autonomy, and political engagement are characteristics of agroecology that can be implemented at both farm and food system level (Dumont et al., 2021). As with the ecological principles, they are designed to inform locally-adapted technologies and practices. However, in addition, the socioeconomic principles aim to enhance overall food systems function through "equitable distribution of resources, political power, and economic and social benefits between system's actors and with future generations" (Dumont et al., 2021).

A further set of agroecological principles was proposed by the CIDSE (2018). These principles were developed to address concerns of co-optation of the term *agroecology*. Increased interest in agroecology has raised concerns that proponents of alternative farming systems such as organic, integrated pest management, and sustainable intensification, may associate themselves with agroecology and in doing so dilute the concept to an approach that deviates only slightly from "business as usual" agriculture, retaining many of the detrimental impacts (Miguel A Altieri, Nicholls, & Montalba, 2017). Recognising agroecology as all of a science, a practice and a socio-political movement, the CIDSE are wary of growing interest in only the technical dimension and the neglect of principles related to food sovereignty, which they view as being interdependent with agroecology (Holt-Giménez & Altieri, 2013).

Accordingly, four essential dimensions of agroecology are defined: environmental; social and cultural; economic; and political (CIDSE, 2018). The principles are a clear demonstration of the CIDSE's dedication to the socio-political dimensions of agroecology: 18 of the 24 principles are associated with these dimensions, while only six are associated with the environmental or ecological dimension of agroecology. From this perspective, agroecology has retained its ecological roots, but has developed broad goals of alleviating hunger, empowering local communities, and food system sustainability (CIDSE, 2018). While reflective of the evolution of agroecology over the last 50 years, this full set of principles is less relevant at the farm level than those of Nicholls and co-authors (2016) and Dumont (2021). Farmers cannot take full responsibility for such ambitious goals, and so these principles appear less well suited to guide farm-level AET.

Finally, a further set of agroecological principles is outlined by Wezel and co-authors (2020). This consolidated list of 13 principles, developed following the framework outlined in the HLPE report (2019), draws on the work of both Dumont and co-authors (2016) and Nicholls

and co-authors (2016), as well the principles outlined by the CIDSE (2018), and the agroecological elements outlined by the FAO (2018). This is a broad set of principles that considers the ecological, social, and economic dimensions of agroecology.

Gliessman (2016) developed a sustainable food systems change framework to outline the different stages of AET and their impact (Figure 2). This includes five levels of change ranging from incremental – influencing the farm-level – to transformational – influencing the food system. This is a helpful system for organising the principles of agroecology. Wezel (2020) highlighted that those principles associated with incremental farm-level change are generally those concerned with the ecological dimension of agroecology, and these map to the bottom half of Figure 2. Principles associated with wider food system transformation generally relate to the social, economic, and political dimensions of agroecology, and map to the top half of Figure 2.

Mapping each principle to Gliessman's (2016) framework goes some way towards illustrating a transition pathway towards sustainable food systems based on the agroecological approach (Wezel et al., 2020). This begins with farmers breaking the dependence on external inputs and culminates in a just and sustainable global food system. However, viewing the process of food system transformation in this way perhaps creates a disconnect between the different dimensions of agroecology. From this perspective, ecology is most relevant to farm management, while social, economic, and political dimensions are less relevant. Dumont and co-author's (2021) noted that the principles ought to be interpreted broadly. For example, a goal of input reduction may motivate restricted use of chemicals at a farm level, but it may also motivate a more localised food system with lower fuel dependency.

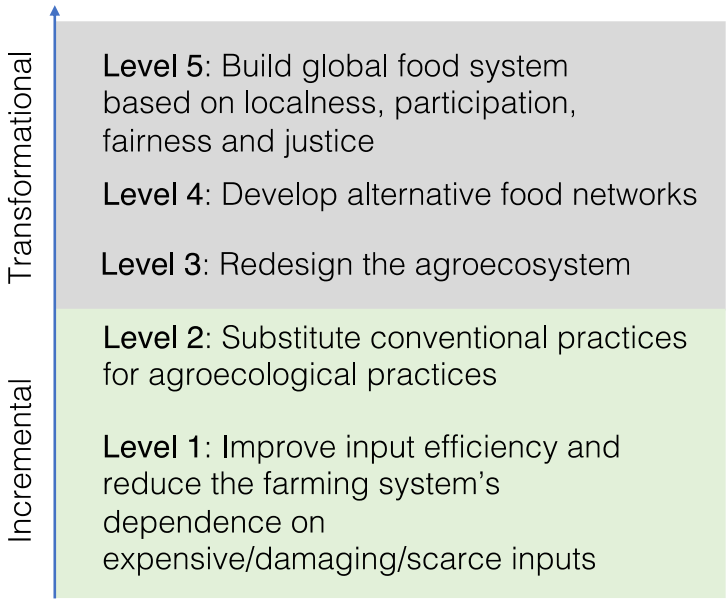

Figure 2. Gliessman's agroecological transition framework. Following Gliessman (2016).

The current sets of agroecological principles are not without their critics. While, on one hand, agroecology necessitates local, context-dependent solutions, on the other hand, weak specification of agroecology leads to an ambiguous concept and poor generalisability of research. Kapgen and Roudart (2020) contend that the absence of a suitable set of principles, citing those proposed by the FAO (2018) as too generic and those proposed by Dumont and co-authors (2016) as too specific, could explain the lack of adoption of the principled-based approach in the management and evaluation of agroecological projects. Nevertheless, research efforts to better define agroecology as a concept through a set of principles have led to a clear convergence of themes. Table 3 presents the agroecological principles outlined in several key publications, and categorises them into common themes.

Defining agroecology using a set of principles is a rational approach for comprehensively covering what is now a broad concept, and also to ensure that it is not reduced to a specific set of practices. There is now clear consensus that agroecology has significant social, economic, and political dimensions. However, it is less clear how each of the principles associated with these dimensions relate to farm-level transition. Clearly a significant component of farm-level AET involves shifting towards ecological farm management, but to what extent can themes such as social values, locality, governance, participation, autonomy, and circular and solidarity economy also be influenced at the farm-level? It is important to establish which of these are relevant at the farm level and through which activities they can be realised.

Table 3. Collated agroecological principles and their corresponding themes. These principles have been taken from the corresponding key publication that defines agroecological principles.

Category	**Principle**	**Author**
Recycling	Preferentially use local renewable resources and close as far as possible resources cycles of nutrients and biomass.	Wezel (2020)
	Enhance the recycling of biomass, with a view to optimising organic matter decomposition and nutrient cycling over time	Nicholls (2016), Dumont (2021)
	More recycling means agricultural production with lower economic and environmental costs.	FAO (2018)
	Agroecology optimises and closes resource loops (nutrients, biomass) by recycling existing nutrients and biomass in farming and food systems.	CIDSE (2018)
Efficiency	Reduce or eliminate dependency on purchased inputs and increase self-sufficiency.	Wezel (2020)
	Minimise losses of energy, water, nutrients and genetic resources by enhancing conservation and regeneration of soil and water resources and agrobiodiversity	Nicholls (2016), Dumont (2021)
	Agroecology eliminates the use of and dependency on external synthetic inputs by enabling farmers to control pests, weeds and improve fertility through ecological management.	CIDSE (2018)
	Innovative agroecological practices produce more using less external resources.	FAO (2018)
Soil Health	Secure and enhance soil health and functioning for improved plant growth, particularly by managing organic matter and enhancing soil biological activity.	Wezel (2020)
	Provide the most favourable soil conditions for plant growth, particularly by managing the organic matter and by enhancing soil biological activity	Nicholls (2016) Dumont (2021)
	Agroecology, builds and conserves life in the soil to provide favourable conditions for plant growth.	CIDSE (2018)
Livestock	Ensure animal health and welfare.	Wezel (2020)

Category	Principle	Author
Biodiversity	Maintain and enhance diversity of species, functional diversity and genetic resources and thereby maintain overall agroecosystem biodiversity in time and space at field, farm and landscape scales.	Wezel (2020)
	Diversify species and genetic resources in the agroecosystem over time and space at the field and landscape level	Nicholls (2016), Dumont (2021)
	Agroecology optimises and maintains biodiversity above and below ground (a wide range of species and varieties, genetic resources, locally-adapted varieties/breeds, etc.) over time and space (at plot, farm and landscape level).	CIDSE (2018)
	Diversification is key to agroecological transitions to ensure food security and nutrition while conserving, protecting and enhancing natural resources.	FAO (2018)
Synergy	Enhance positive ecological interaction, synergy, integration and complementarity amongst the elements of agroecosystems (animals, crops, trees, soil and water).	Wezel (2020)
	Enhance beneficial biological interactions and synergies among the component of agrobiodiversity, thereby promoting key ecological processes and services	Nicholls (2016), Dumont (2021)
	Strengthen the “immune system” of agricultural systems through enhancement of functional biodiversity – natural enemies, antagonists, etc., — by creating appropriate habitats	Nicholls (2016), Dumont (2021)
	Agroecology enhances positive interaction, synergy, integration, and complementarities between the elements of agro-ecosystems (plants, animals, trees, soil, water, etc.) and food systems (water, renewable energy, and the connections of re-localised food chains).	CIDSE (2018)
	Building synergies enhances key functions across food systems, supporting production and multiple ecosystem services.	FAO (2018)
Resilience	Diversify on-farm incomes by ensuring that small-scale farmers have greater financial independence and value addition opportunities while enabling them to respond to demand from consumers.	Wezel (2020)

Category	Principle	Author
	Agroecology supports climate adaptation and resilience while contributing to greenhouse gas emission mitigation (reduction and sequestration) through lower use of fossil fuels and higher carbon sequestration in soils.	CIDSE (2018)
	Agroecology primarily helps provide livelihoods for peasant families and contributes to making local markets, economies and employment more robust.	CIDSE (2018)
	Enhanced resilience of people, communities and ecosystems is key to sustainable food and agricultural systems.	FAO (2018)
Knowledge	Enhance co-creation and horizontal sharing of knowledge including local and scientific innovation, especially through farmer-to-farmer exchange.	Wezel (2020)
	Create collective knowledge by recognising the value of traditional, empirical, scientific knowledge and know-how, and by facilitating their exchanges between actors applying agroecology, including between peers and between generations	Dumont (2021)
	Agroecology is knowledge-intensive and promotes horizontal (farmer-to-farmer) contacts for sharing of knowledge, skills, and innovations, together with alliances giving equal weight to farmer and researcher.	CIDSE (2018)
	Co-creation and sharing of knowledge: agricultural innovations respond better to local challenges when they are co-created through participatory processes.	FAO (2018)
Social Values	Build food systems based on the culture, identity, tradition, social and gender equity of local communities that provide healthy, diversified, seasonally and culturally appropriate diets.	Wezel (2020)
	Support dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers, based on fair trade, fair employment and fair treatment of intellectual property rights.	Wezel (2020)
	Offer good living and working conditions for agroecological practitioners of the defined system, including through the use of the profits obtained from economic activity to remunerate workers and reach social objectives rather than to maximise the return on the capital invested	Dumont (2021)
	Participate in the development of social embeddedness of food systems through farmer, consumer, extension, and scientific networks that support (in) organic inputs exchanges (e.g. compost, machinery, knowledge) and the exchange of output based on solidarity economy	Dumont (2021)

Category	Principle	Author
	Agroecology is rooted in the culture, identity, tradition, innovation and knowledge of local communities.	CIDSE (2018)
	Agroecology contributes to healthy, diversified, seasonally- and culturally-appropriate diets.	CIDSE (2018)
	Agroecology creates opportunities for and promotion of solidarity and discussion between and among culturally diverse peoples (e.g. different ethnic groups that share the same values yet have different practices) and between rural and urban populations.	CIDSE (2018)
	Agroecology respects diversity between people in terms of gender, race, sexual orientation and religion, creates opportunities for young people and women and encourages women's leadership and gender equality.	CIDSE (2018)
	Agroecology supports peoples and communities in maintaining their spiritual and material relationship with their land and environment.	CIDSE (2018)
	Human and social values: protecting and improving rural livelihoods, equity and social well-being is essential for sustainable food and agricultural systems.	FAO (2018)
	Culture and food traditions: by supporting healthy, diversified and culturally appropriate diets, agroecology contributes to food security and nutrition while maintaining the health of ecosystems.	FAO (2018)
Locality	Connectivity: ensure proximity and confidence between producers and consumers through promotion of fair and short distribution networks and by re-embedding food systems into local economies.	Wezel (2020)
	Contribute to the development of local food systems, by promoting local employments and local technologies, by minimising distances between production, transformation and commercialisation steps, and by promoting physical, intellectual and economic access to local markets.	Dumont (2021)
	Agroecology promotes fair, short distribution networks rather than linear distribution chains and builds a transparent network of relationships (often invisible in formal economy) between producers and consumers.	CIDSE (2018)
	Agroecology harnesses the power of local markets by enabling food producers to sell their produce at fair prices and respond actively to local market demand.	CIDSE (2018)

Category	Principle	Author
Governance	Land and natural resource governance: strengthen institutional arrangements to improve, including the recognition and support of family farmers, smallholders and peasant food producers as sustainable managers of natural and genetic resources.	Wezel (2020)
	Take decisions based on democratic models implying balanced power relations between system actors, horizontal exchanges, transparent relationships, non-racial, sexual, gender, religious and cultural discrimination, and no decision based on members' assets	Dumont (2021)
	Participate in political actions to promote agroecological principles and the conditions of their applications	Dumont (2021)
	Agroecology does not necessarily require expensive external certification as it often relies on producer-consumer relations and transactions based on trust, promoting alternatives to certification such as PGS (Participatory Guarantee System) and CSA (Community-Supported Agriculture).	CIDSE (2018)
	Agroecology prioritises the needs and interests of small-scale food producers who supply the majority of the world's food and it de-emphasizes the interests of large industrial food and agricultural systems.	CIDSE (2018)
	Agroecology puts control of seed, biodiversity, land and territories, water, knowledge, and the commons into the hands of the people who are part of the food system and so achieves better-integrated resource management.	CIDSE (2018)
	Agroecology requires a set of supportive, complementary public policies, supportive policymakers and institutions, and public investment to achieve its full potential.	CIDSE (2018)
	Agroecology encourages forms of social organisation needed for decentralised governance and local adaptive management of food and agricultural systems. It also incentivises the self-organisation and collective management of groups and networks at different levels, from local to global (farmers organisations, consumers, research organisations, academic institutions, etc).	CIDSE (2018)
	Responsible governance: sustainable food and agriculture requires responsible and effective governance mechanisms at different scales – from local to national to global.	FAO (2018)
Participation	Participation: encourage social organisation and greater participation in decision-making by food producers and consumer to support decentralised governance and local adaptive management of agricultural and food systems.	Wezel (2020)

Category	Principle	Author
	Agroecology can change power relationships by encouraging greater participation of food producers and consumers in decision-making on food systems and offers new governance structures.	CIDSE (2018)
Autonomy	Ensure autonomy in terms of viability and decision making from markets, economic actors (e.g. clients, agrifood businesses), and policies (e.g. subsidies) up and downstream of the system, and more particularly from actors external to the agroecological approach	Dumont (2021)
	Agroecology promotes diversification of on-farm incomes giving farmers greater financial independence, increases resilience by multiplying sources of production and livelihood, promoting independence from external inputs and reducing crop failure through its diversified system.	CIDSE (2018)
	Agroecology reduces dependence on aid and increases community autonomy by encouraging sustainable livelihoods and dignity.	CIDSE (2018)
Solidarity Economy	Agroecology is built on a vision of a social and solidarity economy.	CIDSE (2018)
	Circular and solidarity economies that reconnect producers and consumers provide innovative solutions for living within our planetary boundaries while ensuring the social foundation for inclusive and sustainable development	FAO (2018)

1.3.4. Agroecology in Scotland

Several organisations in Scotland promote agroecology for sustainable food production. It is at the heart of Soil Association Scotland's vision for sustainable agricultural development – "farming with nature" is viewed as a means of tackling climate change, enhancing wildlife, and empowering farmers and communities (Soil Association Scotland, 2021). Further, the manifesto for agricultural policy change published by The Landworkers' Alliance (LWA), a union of farmers and land-based workers, is based on the principles of agroecology: value local produce and producers; food sovereignty and justice; land diversification and access; support agroecological farm management; local food economies; GMO restriction; education; and participation (LWA, 2021). Finally, The Food Farming and Countryside Commission, a charity that works to improve the sustainability of agriculture and land use in the UK, promote a plan for transition to agroecology by 2030 (Food Farming & Countryside Commission, 2021).

There are therefore several proponents of agroecology that operate in Scotland, but so far a lack of supporting policies. In contrast, agroecology is influential in France's agricultural policy, with agroecological practices legally recognised as a route to delivering sustainable agricultural transition (Ajates Gonzalez, Thomas, & Chang, 2018; Wezel et al., 2018). With growing recognition that urgent changes in food production are required to address climate change and the biodiversity crisis, it is conceivable that Scotland will follow suit. As such, a deeper understanding of AET, which is unique to different environments, cultural norms, and political contexts, is required in Scotland.

Additionally, growing interest in agroecology in Scotland necessitates care in its definition and communication. Scotland's Arable Climate Change Group is one of a number of farmer-led groups that has been recently established with the purpose of providing the Scottish Government with recommendations on how the sector can play a role in combatting climate change. The group believe that tackling climate change will require a holistic approach to farm management, and that benefits can be realised through a combination of applied science and farmers' common sense and experience (The Arable Climate Change Group, 2021). Specifically, the group endorse an Integrated Farm Management (IFM) approach to enhancing the sustainability of Scottish agriculture and make explicit reference to the need for agroecological practices.

> The IFM approach mirrors the principles of Climate Smart Agriculture, recognising the critical role that agriculture plays in not only climate change mitigation but also the delivery of nature-based solutions through agroecological and regenerative practices, underpinning vibrant rural communities and the tourism and food and drink industries from which they stem (The Arable Climate Change Group, 2021).

Certainly, there is overlap between the practices of IFM and agroecology, but these approaches are not synonymous, with agroecology tied to farm and food system redesign while IFM is a greening of current agricultural systems.

Moreover, there are many other alternative approaches to agriculture that share some of the objectives and practices of agroecology: organic, regenerative and conservation agriculture all aim to build healthy soils and reduce or remove dependence on synthetic chemicals. Another approach, sustainable intensification (SI), has been drawn into the conversation on agroecological development in the UK (Lampkin et al., 2015). SI is a concept that divides the scientific community: it is viewed by some as a viable means of simultaneously addressing global issues of food security and environmental degradation, while others see an oxymoron lacking the weight of credible science (Mahon, Crute, Simmons, & Islam, 2017).

While aspects of sustainable intensification are aligned with agroecology, some have warned of the threat of co-optation by greenwashed alternative approaches to agriculture, a group to which some believe modern interpretations of SI belong (Miguel A Altieri et al., 2017). Practices such as precision farming, through which chemicals can be more selectively applied to the crops that need them most, are a positive move towards reducing the levels of application of synthetic chemicals. Indeed, precision agriculture is viewed favourable among Scottish farmers as an approach to enhancing the sustainability of farming systems (Macgregor & Warren, 2006). However, agroecologists would contend that practices that do not aim both to break the dominant monoculture cropping systems, and for the elimination of synthetic inputs through the design of beneficial ecological relations, cannot be considered part of a transformational agroecological approach (Gliessman, 2016).

Despite clearly growing interest in agroecology (Mason et al., 2021), there are few investigations specific to Scottish farms. Padel and co-authors (2020) conducted case studies of 14 UK farms in AET for insights into the pathways through which transitions take place. Wach (2021) investigated sheep farming in the Scottish Highlands and contended that there is an inherent conflict between capitalism – more specifically, market dependency – and

agroecology. Finally, a Scottish study used co-constructed mental models to find that scientists were familiar with agroecology although held different interpretations, while farmers were not familiar with the term (van Hulst, Ellis, Prager, & Msika, 2020) .

1.3.5. What does Agroecology Mean at the Farm Level

Having considered the various sets of agroecological principles that have been proposed in recent years, while agroecology as a concept is broad, there is widespread consensus on the encompassing themes. However, it is important to understand how the principles, and by extension the different dimensions, of agroecology relate to farm-level AET. Recognition of the problems of our modern food and agriculture systems has resulted in growing interest in AETs (Anderson et al., 2019; Willett et al., 2019). One active area of research at the farm level is investigation of the way in which AET takes place. Addressing this is key to closing the gap between agroecological theory and practice.

Investigating AET on livestock farms in Belgium, Tessier and co-authors (2021) demonstrate that agroecological *pathways of action* can be identified on a range of different farming systems, including conventional and organic. The authors completed semi-structured interviews with farmers to identify the practices through which agroecological principles were implemented. Their grounded theory approach allowed for the emergence of novel practices and activities that otherwise would not have been identified as agroecological but clearly fed into one or several of the principles (Tessier et al., 2021). The identified pathways could contribute to any or all of the ecological, social, and economic dimensions of agroecology.

The research suggests that it is impractical to expect that farms' AETs draw on all of the principles of agroecology, and this is supported by further studies. In linking agroecological theory to practice, Toffolini and co-authors (2019) uncover four *ways of acting* arising from the activities of eight farms undergoing AET. The studied farms were either self-identified as in AET or were identified as using practices associated with agroecology. Further studies of AET appear to set the adoption of specific management practices associated with agroecology as the minimum inclusion criterion. Padel and co-authors (2020) evaluated Hill's *efficiency, substitution, redesign* (ESR) (1996) and Sutherland's *trigger events* (2012) frameworks in case studies of 14 UK farms in AET. Some of the included farms were undergoing more substantial change but five were implementing a single farm management change – direct drilling. Similarly, swapping herbicide application for cover cropping and mechanical trimming was

the only inclusion requirement for farmers in a transdisciplinary study investigating vineyard AET (Teschner & Orenstein, 2021).

An issue with focussing specifically on practices is that practices alone are not sufficient identifiers of agroecological systems, since many practices associated with agroecology are also widely implemented in conventional farming systems (Teixeira et al., 2018; Tittonell, 2020). This critique is not to suggest that farms in AET should demonstrate implementation of each agroecological principle, although this is a technical definition provided by some authors (Dumont, Gasselin, & Baret, 2020; Stassart et al., 2012). It would appear reasonable that implementation of a subset of the principles by farmers would be sufficient in identifying farms in transition, especially given agroecology is a concept that now extends well beyond the farm level. Responsibility must therefore be shared by actors across the food system. Indeed, this is the approach adopted by Dumont and co-authors (Dumont et al., 2021), who developed the *justification of practices* framework. The framework aims to identify farms that are oriented towards agroecology by counting the number of agroecological principles that are implemented. A farm can be considered at least oriented towards agroecology if it implements the greatest number of principles in a given context. Therefore, identification as agroecological (or orientation towards) is not absolute, rather relative to other farms sharing that context (Dumont et al., 2021).

Tittonell (2020) adopted an alternative approach to conceptualising farms in AET by postulating that farms successful in improving the sustainability of food and agriculture systems are characterised by resilience and adaptability, and proposed an evaluation framework based on the assessment of these characteristics. Does this imply that farms in AET can be defined as those implementing changes to improve farm resilience and adaptability? Is this a valid simplification?

Therefore, while the concept of agroecology is defined comprehensively, its manifestation at the farm-level appears to be highly variable. This is particularly challenging to understand as it is an approach that may be actualised differently in different farming contexts. If agroecology is to be practically useful as a concept to guide a transition to more sustainable farming systems, we need to understand what people mean by agroecology in those specific contexts, and how their interpretations can address the unique challenges of that context.

1.3.6. A Paradigm Shift in Agricultural Research

The challenge, therefore, is to understand how agroecology is conceptualised and how it can contribute to beneficial change in specific farming contexts. Several prominent sustainable agriculture scholars have advocated for research grounded in alternative paradigms to the dominant positivist approach.

The agricultural achievements of the Green Revolution would not have been possible without reductionism and the positivist paradigm (Douthwaite et al., 2003; Pretty, 1995). Positivism views reality as a concrete entity that can be understood by deconstruction to its component parts. As such, investigation requires a high degree of control, and the isolation and removal of individual variables to illuminate causal relationships and dependencies. The innovations of the Green Revolution arose in this way: consider, for example, the isolation and selection of desirable traits in hybrid seed varieties (Borlaug, 1968), the Haber-Bosch process (Erisman et al., 2008), or the development of modern field trials (Fisher, 1992). Each innovation was achieved through a reduction to component parts, empirical data, and experimentation under highly controlled conditions.

Despite the positives of last century's agricultural revolution, people and planet have also felt the repercussions of intensification (Willett et al., 2019). Reductionist science has greatly enhanced agricultural productivity but some argue it has also contributed to environmental and cultural decline (Clements & Shrestha, 2004). Alternative approaches to agriculture have therefore developed as a response.

> This need for a paradigm shift obviously presents many methodological difficulties, especially for a scientific establishment where small-plot research methods and Baconian science are firmly entrenched. The overall goal of the new philosophy is to integrate biological and cultural knowledge into agroecosystems to the greatest extent possible and to embrace a wider suite of criteria to use in evaluating success. This would involve moving away from a symptom focus to a vision for agroecosystem design (Clements & Shrestha, 2004).

The dominance of the positivist paradigm and the resulting practice-oriented research focus is inhibiting and even contradictory to the development of sustainable agriculture (Pretty, 1994). *Sustainable* can be defined as an ability to adapt to the environment. Therefore, *sustainable* agricultural practices cannot be separated from the environment, or context, in which they are

applied. This environment is different for every farmer, be it due to variation in natural, socioeconomic, or political factors. What is sustainable, or even feasible, for one farmer might not be for a neighbour.

Pretty (1994) outlines five key principles that identify alternative paradigms as valuable to sustainable agricultural research: sustainable agriculture cannot be defined as a fixed set of practices; problems can be interpreted differently; the solution-problem cycle is continuous – one problem always leads to another; continuous learning is key; and multiple perspectives should be sought through learning systems. Each principle encourages the integration of complexity and uncertainty into the research process, standing in stark contrast to reductionism which seeks to deconstruct complexity and eliminate uncertainty.

Importantly, Pretty's principles are strongly aligned with the concept of agroecology: principle-based approaches are emphasised over practice-based approaches (Kapgen & Roudart, 2020); context is inseparable from viable solutions (Nicholls et al., 2016); and co-creation and sharing of knowledge underpins the entire approach (Wezel et al., 2020). Based on this final principle, participation has become a core component of agroecological research (Bezerra, Franco, Souza-Esquerdo, & Borsatto, 2019; Chaparro-Africano & Naranjo, 2020; Méndez, Caswell, Gliessman, & Cohen, 2017; Thrupp, 2004). Additionally, embracing context and complexity encourages systems thinking (Stuart B Hill, 1998): considering agroecosystems in their entirety rather than in their component parts allows for the capturing of emergent properties (Clements & Shrestha, 2004). The holistic, ecology-based approach to agriculture juxtaposes the dominant reductionist, technocentric approach: rather than treating symptoms it seeks to identify causes and redesign the system (Stuart B Hill, 1998).

The change that is being called for in agricultural research is therefore not tied to any specific paradigm, rather, it is a shift away from the dominant positivist position to paradigms closer to the interpretivist end of the ontological spectrum.

> [The] positivist approach… has led to the generation of farming technologies that have been applied widely and irrespective of local context. Where it has been possible to influence and control farmers, either directly or through economic incentives or markets, agricultural systems have been transformed. But where neither the technologies have fitted local systems nor farmers been controlled, then agricultural modernization centered on positivist science has passed rural people by (Pretty, 1995).

From this perspective, agroecology does not simply represent a collection of new practices to be integrated within our conventional agricultural systems. Rather, it represents an entirely different way of thinking about agricultural progress.

1.3.7. Systems Thinking

Systems thinking is an alternative school of thought to the positivist paradigm that appears particularly well aligned to explorations of our conceptualisations of agroecological farming systems. Systems thinking can broadly be split into *hard* and *soft* approaches.

> The first ("hard") approach comes from a pedigree that includes systems analysis, systems engineering, cybernetics, and ecosystem biology. Assuming a world of transforming systems, the "hard" systems scientists in agriculture seek to design new agro-ecosystems that are at once productive, stable, equitable, and sustainable. In the "soft" approach, with its foundation in cognitive science, the systemicity is transferred from the world to the way of investigating the world (Bawden, 1991).

The hard systems approach to sustainable agriculture research originated after it was recognised that the technologies of the Green Revolution were not being successfully adopted by many farmers in developing countries (Simmonds, 1986). Such farms were better considered as systems with needs, constraints, diversity, and complexity, and so Farming Systems Research (FSR) emerged (Conway & Barbier, 1988). Hard systems approaches have continued in different forms, from the development of cropping, pest, and disease models to the application of permaculture for the design of agroecosystems (Ferguson & Lovell, 2014; Klerkx, van Mierlo, & Leeuwis, 2012). However, considerably less attention has been given to soft systems approaches, which are concerned with structuring our conceptual models of reality.

Management science lays claim to several well-established soft systems approaches, most notably, SSM and cognitive mapping (Eden & Ackermann, 2006). These methods are suitable for application to problems that have multiple actors with different perspectives, objectives, and values (Mingers & Rosenhead, 2004; T. G. Williams, Guikema, Brown, & Agrawal, 2020). They provide frameworks for us to structure and understand complex problems from different perspectives, frequently with an aim of facilitating beneficial change. Their philosophical positioning is closer to the interpretivist end of the ontological spectrum, and they aim to embrace and make sense of complexity, rather than attempt to remove it.

Soft systems methods offer a means of capturing the context and nuance that is necessary to account for in explorations of sustainable farming transitions. While SSM has been acknowledged as potentially suitable for exploring such problems (Bawden, 1991; Pretty, 1995), there are currently no studies that have applied the method to explore agroecology. Cognitive mapping has been used to explore the conventional farmers' and scientists' understandings of agroecology in Scotland (van Hulst et al., 2020). However, this research showed that these farmers were unfamiliar with the concept and so it remains necessary to understand the approach from the perspectives of those that are implementing it.

1.3.8. Critical Systems Thinking

Related to soft systems thinking is the critical systems thinking tradition. The most prominent method associated with critical systems thinking is CSH, which was developed by Werner Ulrich (W. Ulrich, 2003). CSH defines systems in the same way as soft systems thinking – conceptual mental models – but is distinct in that it emphasises reflection on the assumptions and judgements that underpin the systems of interest. CSH offers a multi-faceted framework for exploring perspectives on complex issues, particularly those in which coercion and power-asymmetries are influential. It has been applied to several agricultural problems, involving GM crops (Carr & Levidow, 2000), sustainable rice supply chains (Elyasi & Teimoury, 2023), and beef farming in Indonesia (Setianto, Cameron, & Gaughan, 2014), however, it has not yet been applied to specifically explore agroecology.

Ulrich suggests that the principles that underpin CSH ought to permeate through all systems research and existing conceptualisations of critical systems thinking do not offer frameworks that sufficiently emphasise reflection (W. Ulrich, 2003). He emphasises that this perspective is distinct from the view that critical systems thinking relates only to methodological choice. Jackson and Keys (1984) proposed the System of Systems Methodologies which offered analysis of different problem types and the corresponding suitable methodologies. The analysis outlines that problems of lower complexity and without a behavioural dimension are better suited to hard methods, while more complex problems subject to different interpretations require soft methods (Figure 3). Ulrich proposes that this critical approach to selecting suitable methods is only one aspect of critical systems thinking, which is more broadly characterised by reflection on the judgements that shape our understandings (W. Ulrich, 2003).

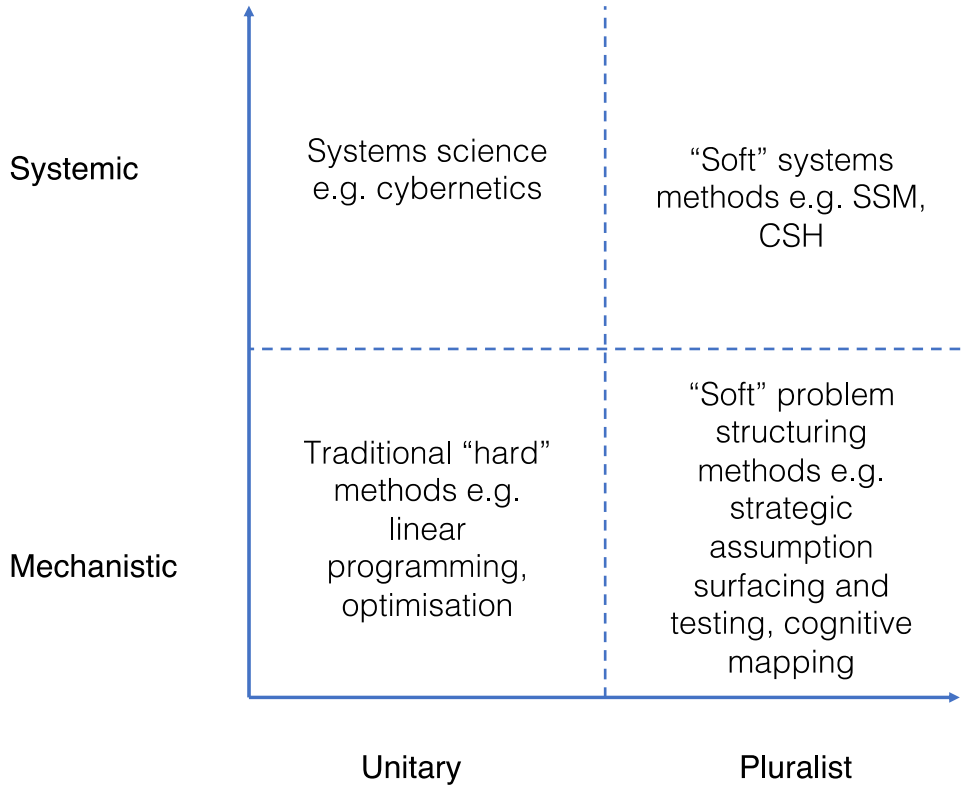

Figure 3. Problem types and corresponding suitable methodologies based on the System of Systems Methodologies analysis. Based on (Jackon & Keys, 1984).

Soft systems approaches may be applied to capture different perspectives on problems with a behavioural or social dimension. Critical systems heuristics emphasises reflecting on these perspectives to better understand why they are held (W. Ulrich & Reynolds, 2010). This is actualised through the practice of boundary critique – the process of articulating and questioning the judgements that inform our understanding of an issue. The CSH framework provides a series of 12 boundary questions which, when considered together, can be used to seek a comprehensive understanding of a particular perspective. These boundary questions are organised into four categories: motivation, control, knowledge, and legitimacy (Table 4).

The boundary questions are designed to facilitate reflection on the key judgements we make that shape our perspective on a problem. In doing so, CSH aims to provide a mechanism that enables both a clearer understanding of the judgements that inform different perspectives, and the ability to substantiate normative claims.

Table 4. CSH framework (following Ulrich & Reynolds, 2010)

Sources of Influence	**Boundary Questions**	
Sources of Motivation	Beneficiary	1. Who ought to be/is the intended beneficiary of the system?
	Purpose	2. What ought to be/is the purpose of the system?
	Measure of Improvement	3. What ought to be/is the system's measure of success?
Sources of Control	Decision Maker	4. Who ought to be/is in control of the conditions of success of the system?
	Resources	5. What conditions of success ought to be/are under the control of the system?
	Decision Environment	6. What conditions of success ought to be/are outside the control of the decision maker?
Sources of Knowledge	Expert	7. Who ought to be/is providing relevant knowledge and skills for the system?
	Expertise	8. What ought to be/are relevant new knowledge and skills for the system?
	Guarantor	9. What ought to be/are regarded as assurances of successful implementation?
Sources of Legitimacy	Witness	10. Who ought to be/ is representing the interests of those negatively affected by but not involved with the system?
	Emancipation	11. What ought to be/are the opportunities for the interests of those negatively affected to

Sources of Influence	Boundary Questions	
		have expression and freedom from the worldview of the system?
	Worldview	12. What space ought to be/is available for reconciling differing worldviews regarding the system among those involved and affected?

Boundary critique is the approach by which we examine which information is relevant from a particular perspective, and which elements are not (Midgley, 1992; W. Ulrich & Reynolds, 2010). This process is depicted in Figure 4. If the purpose is to capture relevant information that comprises the system of interest, this can also be achieved by applying alternative soft systems approaches, for example, cognitive mapping. However, a key difference is the emphasis that the CSH framework places on reflection, and understanding why different elements may lie inside or outside the system boundary. It is this distinction that has caused CSH to be of particular interest in problems characterised by coercion or power asymmetry, despite some authors suggesting that all systems methods are unsuitable for addressing such issues (Jackson & Keys, 1984; Midgley, 1997a). CSH aims to provide a level playing field for different perspectives to be shared and understood and as such may be applied to allow for the expression of views of marginalised individuals and groups, with an aim of understanding why these perspectives may deviate from more dominant narratives.

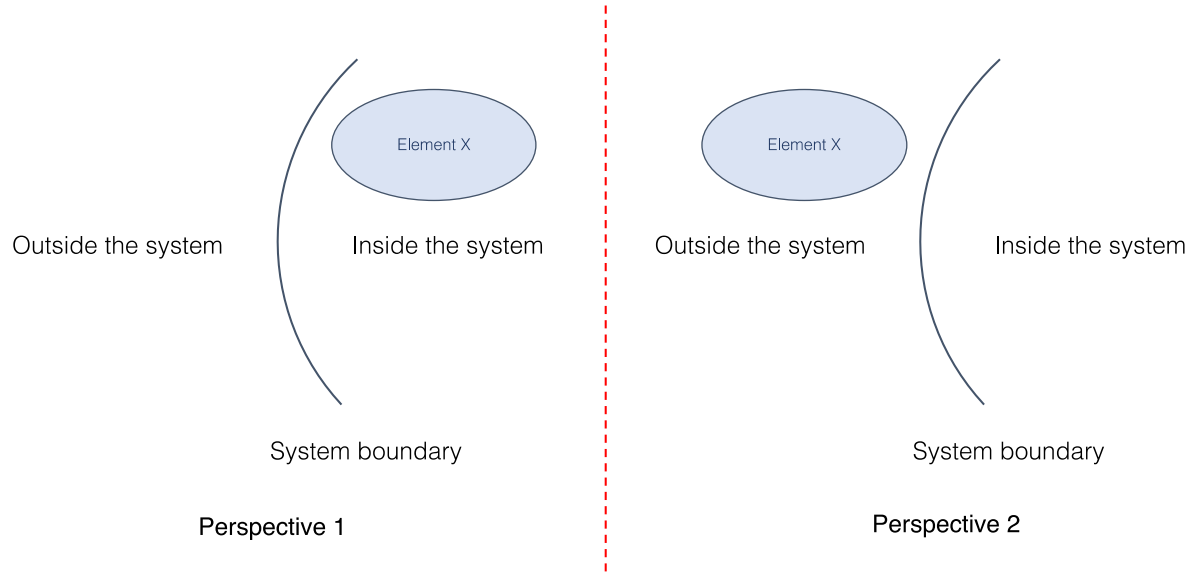

Figure 4. Illustration of boundary critique. CSH may be applied to understand which information is relevant from a particular perspective, and which are not. From Perspective 1, Element X is relevant, while from Perspective 2, it is not.

CSH therefore appears to be a suitable approach for an in-depth exploration of different perspectives on agroecology in Scotland, with an aim on gaining a clear understanding of why this approach may help deliver sustainable transition in the farming sector. While the method appears suitable generally for further applications to complex management problems, problems of sustainable agriculture may be particularly well-aligned given calls for more explicit consideration of the locally adapted contexts in which farming innovations are applied, if they are to be successful and sustained (Conway & Barbier, 1988; Pretty, 1995).

1.4. Research Aims

This research aims to explore agroecology in the context of Scottish agriculture to better understand the role it might play in a sustainable farming transition. To do so, I first explore how agroecology is conceptualised and practically actualised by farmers in Scotland. Then, given the apparent alignment of systems thinking approaches and the context-dependent nature of agroecological farming, I aim to identify the changes in Scottish farming that an agroecological transition would require through the application of a suitable systems framework. A framework of particular interest for this purpose is CSH, however, given that adoption of this method is low compared with soft systems approaches such as SSM and cognitive mapping, before applying the framework I review the CSH literature to better understand its utility. Finally, as well as applying CSH to explore agroecology in Scotland, I

apply the framework in a second case study to further understand and demonstrate its utility as a method for supporting change in the farming sector.

Concisely stated, the research aims are:

1. Explore agroecology in Scotland to better understand the role it might play in sustainable agricultural transition.
2. Discuss the utility of CSH for exploring problems of agricultural transition.

1.5. Research Questions

RQ1: What role can agroecology play in Scotland's agricultural transition?

RQ2: What is the utility of CSH for enhancing understanding in problems of agricultural transition?

Both outlined research questions are of a descriptive, exploratory nature and so are best suited to address using qualitative research methods. An initial review of the agroecology literature indicated that a critical systems approach may be well suited to addressing the complex and context dependent nature of agroecology (RQ1). Given that agroecology is a concept that is presently poorly understood in the Scottish context and there is an absence of evidence demonstrating that this is a viable approach in practice, a preliminary exploration of agroecological farming in Scotland was conducted. This phenomenological exploration of farmers' actualisations of agroecology aimed to verify that agroecology is relevant and viable, and to understand how it is conceptualised in the Scottish farming context. The inductive approach aimed to surface key themes from semi-structured interviews that could be distilled into a concise statement of the "phenomenon" of agroecological farming in Scotland. CSH was then applied, also drawing on the interpretivist research paradigm, to explore different perspectives on agroecological transition in Scotland. In doing so, the opportunities and challenges for agroecology are discussed.

RQ2 focuses on the utility of CSH as an approach to exploring issues of agricultural transition. CSH research and practice to date has not been summarised in the literature and so the first step in addressing RQ2 involved a systematic review of the CSH literature. A further CSH study was then conducted with an agricultural software company in the UK. The goal of this organisation is transformative in that they are aiming to accelerate a shift towards data-driven decision making in UK agriculture. This study differs from the agroecology CSH study, in that

it followed an action research and workshop-based research design. These differences provide a platform from which the versatility of the CSH framework can be demonstrated and discussed with reference to change in the farming sector.

In the conclusion chapter, I synthesise the findings on both the role of agroecology in Scottish agriculture and the utility of CSH for enhancing understanding in each of the case studies in which it was applied. For the latter, I reflect on what distinguishes CSH from alternative soft systems approaches and why problems of farming change may be well-suited to exploration using the CSH framework.

1.6. Thesis Contributions

This thesis enhances our understanding of agroecology in Scotland. It draws on the experiences of farmers in Scotland to describe agroecology as a practice in Scotland and uncovers commonalities in the approach among different farm types and systems. Further, it discusses the routes through which agroecological farmers in Scotland are contributing to change at both a farm and food system level. Reflecting on perspectives of farming in Scotland as it is now and as it would be ideally, this research uncovers practical recommendations for agroecological transition in Scotland, highlighting the importance of supporting a greater diversity of farming systems, the need for action across the entire food system and improved measurement tools to measure farming outcomes, the benefit of nuance and precision when exploring agroecology in practice.

Methodologically, the thesis summarises existing CSH research and provides clarity on the key concepts and terminologies that accompany the method, which is underutilised and seemingly poorly understood. The thesis also reflects on the two applications of CSH – one interview-based and exploratory, the other workshop-based action research – to discuss the effectiveness of CSH for addressing and supporting farming change.

1.7. Thesis Structure

Chapter 2: Actualisations of agroecology among Scottish farmers

This chapter reports a phenomenological exploration of agroecology in Scotland. I first discuss why it is necessary to understand how agroecology is conceptualised and implemented in the Scottish context. I then discuss why this exploration is well-suited to the phenomenological research paradigm and provide an overview of the Trans Positional Cognition Approach

(TPCA). I then distil the key themes that emerged from interviews with 20 agroecological farmers in Scotland into an "essence" of agroecological farming in Scotland. Finally, I discuss the implications of this approach for farming and food system redesign in Scotland.

Chapter 3: Critical systems heuristics - a systematic review

This chapter reviews the CSH literature to date with a focus on providing clarity on the key terminologies and concepts associated with the framework. The review summarises the different problem contexts in which CSH has been applied, and discusses the methodological positioning of CSH, coercion, emancipation, boundary critique, "is" vs "ought to be" framings, and action research with respect to the literature. The review aims clarify these topics with the hope that it may lower the adoption barrier for CSH and encourage more researchers and practitioners to consider the approach.

Chapter 4: Exploring perspectives on agroecological transition in Scotland with critical systems heuristics

Chapter 4 describes an application of CSH to explore perspectives on agroecological transition in Scotland. The chapter discusses the suitability of CSH for exploring this topic and describes the research methodology. The findings are structured following the 12 CSH boundary questions and reflect on perspectives of farming in Scotland as it is and as it ought to be. These are discussed and from them I derive a series of practical recommendations to support agroecological transition in Scotland.

Chapter 5: Exploring data quality with critical systems heuristics

This chapter outlines a second application of CSH in the context of farming change. This workshop-based action research explores the issue of data quality for an agricultural software company aiming to accelerate a transition to data-driven farm management decision-making in UK agriculture. The chapter provides an overview of the organisation and research methodology, before outlining the key actions and recommendation that were uncovered during the workshop. The chapter then reflects on which of these actions were carried out and resulted in beneficial change for the organisation, and the utility of the CSH framework in this action research context is discussed.

Chapter 6: Conclusion

This chapter first reflects on the key learnings about agroecology that have been gained through this research. Firstly, I reflect on the findings of this research to understand what role agroecological farming might play in Scottish farming going forward. I consider the limitations of this research and suggest areas for future research that could deepen our understanding of agroecology from a wider range of perspectives. Secondly, I reflect on CSH and its effectiveness in enhancing understanding in each of the outlined case studies. I discuss the strengths and limitations of each research design, and more generally the suitability of CSH to explore problems of agricultural transition.

Chapter 2. Actualisations of Agroecology Among Scottish Farmers

Publication:

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2.1. Overview

Transformative agroecology challenges industrialised food and farming systems, proposing an alternative vision in which farms are designed around ecological symbioses and embedded within socially just food networks. However, at a policy level, alternative conceptualisations of agroecology have emerged that emphasise on-farm efficiency gains but lack broader objectives of agroecosystem and food system transformation. This phenomenological inquiry explores the agroecological narrative among Scottish farmers and considers its impacts on agroecosystem and food system change. Interviews were conducted across 15 farms in Scotland (20 participants) following the trans positional cognition approach (TPCA). Actualisations of agroecology were found to be value-driven approaches to developing individualised, lower-input farming systems. All farms were attempting to influence agroecosystem change through the application of ecological principles, and most (11/15) were contributing to food system change directly through involvement in alternative food networks. Smaller-scale farmers appear to deliver the most authentic actualisations of transformative agroecology but emphasised more strongly their financial challenges. A key recommendation for policymakers is to strengthen the support mechanisms available for small-scale ecological agriculture.

2.2. Introduction

The term "agroecological transition" now requires clarification, given the diverging conceptualisations of agroecology that have accompanied its increasing institutional acceptance (Giraldo & Rosset, 2018). The extent of food and farming change that might be realised depends on whether agroecology more closely aligns with a "conforming" or "transformative" definition (Levidow, Pimbert, & Vanloqueren, 2014). This dichotomy of interpretations – a top-down set of practices to be integrated into a system that closely resembles business-as-usual, and a food system transformation that fundamentally challenges capitalism – presents a dilemma. The former may provide a gateway to the latter, but it also risks etiolating agroecology to an approach devoid of a social justice objective (Dale, 2020; Schiller, Godek, Klerkx, & Poortvliet, 2020).

Several recent studies have highlighted this tension in practice. In Nicaragua, the incorporation of food sovereignty policies had been a step forward for the agroecological movement, but the impact was diluted by the government's overall hybrid approach that was also supportive of the industrialised food system (Schiller et al., 2020). Similarly, Murguia Gonzalez and co-authors (2020) noted the challenges faced by El Salvador's agroecological movement: engage with policymakers and exist within the industrial system, or risk the movement's credibility by not engaging. Demeter, a certification scheme for produce grown on biodynamic farms in 65 different countries, represents one of the success stories of the agroecological movement. However, research in Denmark with Demeter-certified biodynamic farmers highlighted a need to develop agricultural policy that supports a diverse range of farming approaches so that viability is not contingent on agribusiness and other currently dominant food system actors (Aare, Egmose, Lund, & Hauggaard-Nielsen, 2021). Agroecology may be increasingly recognised by both farmers and institutions, but there is a challenge in developing suitable policy frameworks that are supportive of the transformative narrative (López-García et al., 2020).

Given these diverging conceptualisations of agroecology, we sought to explore how this approach was being implemented at the farm level in Scotland. Farmers cannot take sole responsibility for driving agroecological transition – it requires the engagement of multiple stakeholders in participatory, transdisciplinary processes (Kapgen & Roudart, 2020; Ollivier, Magda, Mazé, Plumecocq, & Lamine, 2018). Lasting sustainable agricultural interventions

require participatory approaches that are recognising of unique farming contexts (Pretty, 1994). Nevertheless, farmers can directly influence the agroecosystem and food system change to which transformative agroecology aspires (Gliessman, 2016) – the former through the implementation of ecological practices, and the latter by integration with alternative food networks. A review of farmers' adoption of soil health practices highlighted that transformative change was linked to modification of farmers' mental models, brought about by, for example, financial pressures or poor health, whereas incremental change involved the integration of new practices that fitted with existing conceptualisations of their farms (Carlisle, 2016). It is not clear, however, whether a greater extent of transformation necessarily follows from such incremental change.

While, theoretically, transition takes place through five distinct levels (Gliessman, 2016) – efficiency enhancement, substitution of practices, agroecological redesign, establishment of alternative food networks, and global food system redesign – transition in practice is not necessarily linear. Padel and co-authors (2020) found that UK farms in agroecological transition did not progress sequentially through the efficiency, substitution, and redesign phases of transition (Stuart B. Hill & MacRae, 1996). Instead, farmers had various entry points to transition and followed no common process of redesign. Other studies have highlighted the diverse mechanisms through which farm-level agroecological transitions can progress (Tessier et al., 2021; Toffolini et al., 2019). With no single starting point or transition pathway, the trajectory and eventual outcomes of transition are unclear without an understanding of farmers' motivations and objectives.

The objective of the study is to identify whether farmers in Scotland are aligned to a transformative vision of agroecology that culminates in food system redesign or are only interested in efficiencies offered by changes in their practices**.** We explore the experiences of farmers actualising agroecology – individuals that identify with this label and who are putting the approach into practice on their farms. We consider the influence of their approaches on both agroecosystem and food system transformation. In doing so, the research aims to better understand the challenges for transformative agroecology consequent of the currently fragmented discourse (Schiller et al., 2020).

2.3. Methodology

This study is a phenomenological exploration of the lived experiences of agroecological farmers in Scotland. Phenomenology was chosen over other qualitative research approaches because the purpose of the study is to understand the way in which agroecology, an emerging approach in the chosen case study area, was actualised by a limited group of farmers. The study is therefore not attempting to build a theory of agroecological farming, rather, it explores the experiences of self-identified agroecological farmers, and considers the implications of their approaches for agricultural transformation (Creswell & Creswell, 2013; Smith & Shinebourne, 2012). Theoretically, agroecology is well-defined, but there is a need to better understand how conceptualisations of this approach are shaping agriculture in practice.

Phenomenological inquiries aim to distil phenomena of interest into their *essences*, or key characteristics. Descriptive phenomenology posits that essences can be described objectively (Giorgi & Giorgi, 2003), whereas interpretivist phenomenology views essences and the subjectivity through which they arise as inseparable (Olekanma, Dörfler, & Shafti, 2022; Shinebourne, 2011). This study positions phenomenology within the interpretivist research paradigm (Dörfler & Stierand, 2021) and favours the trans positional cognition approach (TPCA) (Olekanma et al., 2022), which integrates the descriptive and interpretivist traditions of phenomenology by providing a methodological protocol for managing subjectivity. This is accomplished through bracketing, a process by which researchers attempt to suspend their judgements, but also make transparent the values and knowledge that may influence their interpretation of participants' experiences (Dörfler & Stierand, 2021).

In exploring actualisations of agroecology, Scottish farming was chosen as a case study. Agricultural land use in Scotland is dominated by rough grazing and grasslands. Of the 5.64 million hectares in agricultural production, 466 000 hectares are used for cereal and oilseed production, 28 300 hectares for potatoes, 21 000 for vegetables, and 2 200 for soft fruit (Scottish Government, 2020). Scottish farming is at a pivotal moment, with exit from the European Union having triggered a redesign of agricultural policy. Details of the future policy framework are currently unknown, but the Scottish Government has announced an intention to become a leader in sustainable agriculture in response to the climate and biodiversity crises (Scottish Government, 2022b). To this end, two recent reports have considered agroecology in Scotland. Lozada and co-authors (2022) conducted a survey of Scottish farmers and found that

60% of the 192 respondents had integrated at least one agroecological practice into their farm management. However, it is not clear how, or if, integration of these practices translates into more significant transformation at either the agroecosystem or food system level. Further, Cole and co-authors (2021) identified a need to understand the socioeconomic impacts of farm-level agroecology in Scotland. In considering the impacts of farmers' actualisations of agroecology on agroecosystem and food system change, this research aims to address this knowledge gap.

Interviews with 20 agroecological farmers across 15 farms in Scotland were conducted (Table 5). Farms were of mixed type and size. The interviews were semi-structured and were conducted either in person or remotely over Zoom. Initially, research participants were purposively selected, and subsequent participants were acquired via a snowballing strategy. Participants were required to be farming in Scotland and associate their approach with agroecology. Several participants were recruited through the lead author's own network, as he grew up on an arable farm in Fife, a region in the east of Scotland with some of the country's most fertile agricultural land (Scottish Government, 2020). At the end of each interview, participants were asked whether they knew of any other individuals who might be eligible and interested to participate in the study (Appendix 2). After several interviews, we found repetition in the names that were being recommended for interview and used this as an indication that we were approaching saturation of eligible participants. Several participants were also recruited through internet searches for "agroecology Scotland" and "agroecological farming Scotland". In advance of the interview, participants were provided with a participant information sheet and consent form (Appendix 1).

The type or number of practices or principles implemented by participating farmers did not influence selection – it was only important that they identified their farms as being in some way agroecological. In this way, the interviews could generate insights into the way in which different conceptualisations of agroecology manifest in practice. Interviews sought to understand farmers' approaches and experiences by exploring their background, motivations, objectives, practices, knowledge, and challenges. In doing so, this research considers the implications of different actualisations of agroecology for agricultural transformation. Ten of the interviews were conducted one-to-one but in five cases, two participants were interviewed jointly. The study included farms of all scales: one mixed farm was over 1000 hectares, while two market gardens were producing on less than a hectare. It was deemed important to also include small-scale food producers in the study, given not only the link between agroecology

and small-scale farming, but also its associations with market gardening and permaculture (Ferguson & Lovell, 2014; Morel & Léger, 2016).

Interviews were conducted between October 2021 and February 2022. This research received ethics approval from the Management Science Ethics Committee at the University of Strathclyde. Participants were provided with a study information sheet and consent form prior to taking part in interviews. Data was collected, analysed, and interpreted following the 6 stage TPCA methodology outlined by Olekanma and co-authors (2022). These 6 stages are: 1) data collection, 2) data transcription, 3) text analysis, 4) creation of a data display structure, 5) data validation, and 6) idiographic explanation. Each interview lasted between 45 minutes and 2 hours. During interviews, conscious effort was made to suspend judgements that may influence interpretation of participants' experiences. Bracketing continued through the reviewing of transcripts and identification of participant themes (PTs). Once this had been completed for each participant, the individual themes were grouped across participants, removing repetitions. In this way, the PTs were generated. Consciously attempting to see things from the perspectives of the participants, the PTs were again grouped and interpreted, resulting in the researcher's interpretation of participant themes (Ri-PTs). From the Ri-PTs, an overarching study essence was derived. The ability to step into the shoes of participants was deemed possible because of the lead author's experience in farming, having grown up on an arable farm where he worked each harvest throughout school and his undergraduate studies. PTs, Ri-PTs, and the study essence were developed into a thematic map (Braun & Clarke, 2006), which was sent to participants for validation (10/15 responses).

Table 5. Participant details. All participants were based in Scotland and identified their approaches with agroecology.

Participant(s)	**Farm Type**	**Additional Farming Identifiers**	**Location**	**Farm Size**	**Tenure**	**No. Participants**	**Gender**	**Age**	**New Entrant**
A	Beef	Agroecological beef producers	Highland area	~ 40 hectares	Tenant	2	M, F	30-39	Y
B	Mixed (arable and beef)	Regenerative	Fife	~ 1300 hectares	Owned	1	M	40-49	N
C	Mixed (arable and beef)	Organic (partial)	Fife	~ 530 hectares	Owned	1	M	50-59	N
D	Dairy	Cow with calf, regenerative	Ayrshire	~ 90 hectares	Tenant	1	M	30-39	N
E	Mixed (arable, beef, and sheep)	Regenerative	Fife	~ 570 hectares	Tenant and contract	1	F	30-39	N
F	Mixed livestock	Regenerative	Argyll and Bute	~ 30 hectares	Owned	1	M	60+	N
G	Mixed (arable and pigs)	Regenerative	Fife	~ 200 hectares	Owned	1	M	30-39	N
H	Beef	Regenerative	Ayrshire	~ 120 hectares	Owned	2	M, F	40-49, 60+	Y
I	Market garden	Agroecological market gardeners	Fife	> 1 hectare	Contract	2	M, F	30-39	Y
J	Mixed (arable and poultry)	Regenerative	Fife	~ 650 hectares	Owned and contract	2	M, M	30-39, 40-49	N
K	Co-operative (mainly CSA)	Agroecological CSA	Fife	~16 hectares (2 hectare	Owned	1	M	30-39	Y

Participant(s)	Farm Type	Additional Farming Identifiers	Location	Farm Size	Tenure	No. Participants	Gender	Age	New Entrant
				market garden)					
L	Market garden	Permaculture	Glasgow	> 1 hectare	Council owned (free use)	1	M	30-39	Y
M	Dairy	Organic, cow with calf	Dumfries and Galloway	~ 340 hectares	Tenant	1	M	60+	Y
N	Market garden	CSA, permaculture	Aberdeenshire	~ 3 hectares	Owned	2	M, F	30-39, 40-49	Y
O	Beef	Organic, regenerative	Scottish Borders	~ 240 hectares	Owned	1	F	60+	N

2.4. Findings

The groups of PTs were interpreted to give four Ri-PTs: *reducing dependence on fuel and chemical inputs, actively engaging in learning, tailoring the system to suit the farm, and reflecting personal values*. For the *actively involved in learning* Ri-PT, interpretation was a straightforward process. It was clear that several of the participant themes related to the need to develop new skills and knowledge, and the mechanisms by which farmers could do this. However, the three remaining Ri-PTs were less obvious. For this reason, a discussion between co-researchers to facilitate transpersonal reflexivity is an important step in the TPCA methodology. Initially five Ri-PTs had been identified, but after reflecting on and discussing the assumptions that underpinned the original interpretation of PTs and their groupings, a final group of four Ri-PTs were found to more accurately convey participants' experiences. These Ri-PTs were interpreted at a higher level of abstraction to give the essence of the considered agroecological actualisations: a value-driven approach to developing individualised, lower-input farming systems. Herein, this section outlines each of the finalised Ri-PTs.

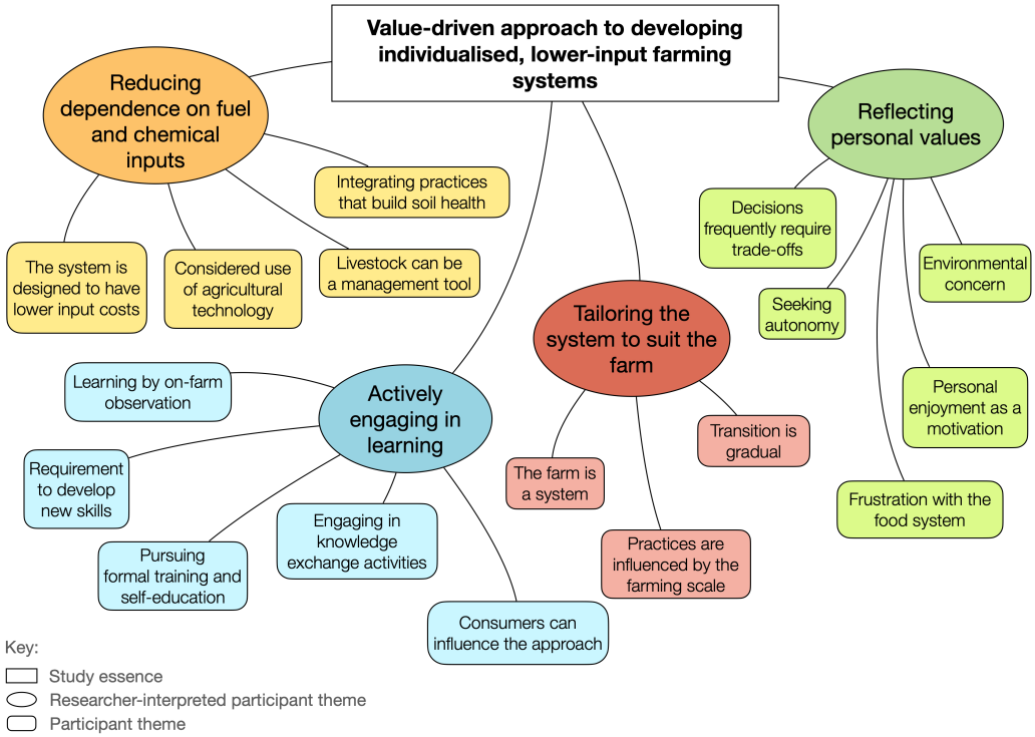

Figure 5. Thematic map developed from interview transcripts. The study "essence" is contained within the rectangular box at the top of the map and is connected to the Ri-PTs in the ovals below, into which feed the PTs. The themes are universal among participants.

2.4.1. *Reducing dependence on fuel and chemical inputs*

Central to each of the study participants' farming approaches was the aim of developing lower-input farming systems. Participants were critical of modern agriculture's high use of fossil fuels and chemicals. This reliance was perceived to be expensive, damaging to the environment, and counter to farmer autonomy. Participants were therefore implementing practices that allowed for reductions in fuel and chemical use.

> What I believe is that we can have the whole farm covered in herbal lays, graze the cows in a regenerative way, not plough, not use any chemicals, and try and work a bit more closely with nature (Participant D).

> Farmers need to stop agrochemicals and need to look at their fossil fuel use (Participant O).

Participants described healthy soils as being vital for the viability lower-input systems. Several participants (B, C, F and H) stated that their soils were the foundation of their farming approach. Importantly, properly functioning soils were perceived to facilitate a transition away from external inputs.

> I expect that the additives we will be using in the future will be more biological and less chemical… but I hope that at some point our soil is working well enough that we don't have to use them (Participant B).

In discussing soil health, participants described a farmer-soil relationship based on reciprocity. Participants believed that catering to the needs of their soils would, in turn, allow their soils to help them.

> It basically comes down to the soil, looking after the soil, hoping and realising that it can help me grow crops (Participant C).

Farmers indicated that this was a change from a more conventionally oriented perspective on farming in Scotland, which Participant A described as "extractive". Participant C, having taken a soil-first approach on his farm for 20 years, spoke of widespread soil degradation on the east coast of Scotland, and noted that his farm had measured increases in soil organic matter during a time when he believed that other local farmers have seen decreases. Participants therefore

viewed their approaches as distinct from more conventional farm management, and saw this as influenced by a recent and evolving understanding of the role of soils in healthy agroecosystems. Participants E and H believed that that soil biology deserves greater attention because of these advancements, in addition to the previous doctrine of managing soil chemistry.

Farmers discussed different practices through which they aim to build soil health and so reduce dependence on external inputs. Farmers with an arable enterprise (B, C, E, G and J) were particularly interested in direct or no-till drilling. By disturbing the soil less, these farmers aimed to improve the soil structure and ultimately the quality of their crops. These minimal cultivation practices have lower fuel requirements. Cover cropping was also highlighted as a route to building soil fertility through green manures, and so reducing fertiliser requirements. However, participants G and J described the challenges that Scotland's temperate presents for the establishment of cover crops in addition to a cash crop in a single growing season. Participants discussed the role livestock could play in building soil health. Several participants (A, B, C and H) were practicing adaptive multi-paddock (AMP) grazing, an approach in which livestock are moved regularly, sometimes multiple times a day. This is a management practice that aims to avoid overgrazing, stimulate grassland productivity, promote biodiversity and build soil fertility. Further, soil health was important to the market gardeners, who discussed observed improvements in the soil after specific practices, namely, incorporating seaweed inputs or local manure, and introducing legumes into the rotation.

While all participants were aiming to integrate practices that reduced input requirements directly or indirectly by building soil health, there was variation in the flexibility with which these practices were implemented. For example, Participant F's perception of the destructive impacts of plough on the soil meant he was highly critical of this practice. Other farmers were more relaxed about the extent of soil disturbance in their farming systems. For arable farmers, direct drilling systems delivered immediate economic benefits through savings on fuel and labour, but this was only the case if the system did not suffer from a yield reduction. Participant E therefore stated the importance of flexibility in the farming system – sometimes ploughing may be the best option, other times it may not. Participant G had only transitioned to a predominantly direct drilling system because he had demonstrated in trials that yields were at least as good as the previous plough-based system. However, there was little motivation for him to further reduce soil disturbance by no-till drilling, perceived to result in a yield reduction, which could not be justified through cost savings or further improvements to soil health.

Further, in arable systems, removing the plough presents an additional challenge of weed build-up. Therefore, integrating this practice can require a trade-off – savings on fuel may come with greater dependence on glyphosate for weed control. Participants expressed different views on such dependence on chemicals, with some believing they still had a role to play in farming systems, while others were entirely against their use (Participant O). Participant C, an arable farmer who had been direct drilling for more than 20 years, saw glyphosate-use as only a temporary problem that will eventually be addressed by advancements in knowledge and technology.

Agricultural technology played a role in supporting reduced input farming, but farmers approached this sceptically. Participant A believed that he was less trusting of technological innovations than conventional farmers. Since reducing inputs – including machinery use – was key to the farming system, any technology brought into their operation could not contradict this approach. There was a belief among participants that technologies could be both expensive and potentially damaging to the environment, and so care was required when considering the long-term interests of the farm. Nevertheless, several participants gave examples of ways in which technology was supporting transitions through lower-input systems, namely, sap testing to allow for the precision treatment of crops, and the development of lower carbon fertilisers (Participant J). Technology was therefore generally perceived to have an important role in participants' farming approaches, but it was considered cautiously.

> I'm not totally against technology… It's about using technology to help you, rather than allowing you to do bad things (Participant M).

2.4.2. Actively engaged in learning

All the study participants described the learning required for changing their businesses. Participants perceived other farmers as a particularly valuable learning resource. Several farmers (Participants B, C, D, I, and J) highlighted the value of visiting other farms to pick up ideas that might translate into their own farming systems. As well as serving a practical purpose, there was also a social element to these visits – farmers enjoyed catching up with their peers in these settings.

> It's a talking shop. When we get together it's just… it's brilliant (Participant C).

In learning from one another, farmers were interested in hearing about different experiences with lower input practices. Participant E emphasised the importance of openness in dialogue with other farmers, and the learning that can be achieved through discussion of failures as well as successes.

> I was at a farm tour with them and they were like, “come into this field, it’s a total disaster don't ever do this”, and that's the kind of things you need to be able to move forward with an idea (Participant E).

As well as discussing the integration of specific practices into the farming system, some participants also described how interaction with their peers could help inform the structure of their businesses. As an example, Participant I, market gardeners, were receiving mentoring from a community supported agriculture (CSA) co-operative. Further, Participant D described both receiving and sharing guidance on business diversification in his interactions with neighbours.

> I’ve actually helped him go onto a milk vending machine business as well, so it’s worked both ways (Participant D).

Farmers transitioning their businesses towards direct sales and closer connection with local customers discussed the required broadening of skills. Participants A, F and K spoke of the importance of learning to market their produce. Specifically, Participant K discussed the adverse impact of neglecting marketing on sales, having seen demand for their produce fall after the first COVID-19 lockdown.

> I think it's just relative to last year when people were falling over themselves for vegetables, like this year we haven't been marketing and we've suffered as a consequence of that (Participant K).

Farmer to farmer knowledge exchange was only one of several learning mechanisms that participants described. Knowledge exchange with universities, research centres, and farming based organisations was also viewed as important for learning. Further, farmers discussed their reading, formal training courses, and a host of free online resources – particularly videos of other farming systems in action. Online material was generally not of other local farming systems, but of farmers around the globe showcasing their systems. Participants A and B described the way in which the principles applied by these farmers, even if farming in very

different climactic conditions, were translatable into their own contexts. Observation was also highlighted as a key mechanism for learning at the agroecosystem level, and was described as important for understanding and evaluating the impacts of changes to the farming system. Examples of the role of observation in farming ranged from the more practical and tangible – such as digging holes to evaluate soil health (Participant C), and seeing less flooding in minimally disturbed fields (Participant B) – to the philosophical – several farmers described following nature's lead. In all cases, farmers used observation as a means of understanding the specific functioning of their own farming systems. Much could be learned from knowledge exchange activities but there remained a need to understand the unique functioning of each farm. Participants engaged in direct sales also described the value of learning from their customers. Participant M highlighted the important role that their customers played in informing the design of their dairy system. Their decision to run a calf at foot dairy was guided by feedback from the public on how they would like the animals to be treated.

2.4.3. Tailoring the system to suit the farm

Participants emphasised that their approaches were tailored to their farms. As opposed to developing their systems from a blueprint, they were designing an approach suited to their own land, climate, and scale. Participants E and J stated their belief that every farm is unique, and the consequent need for flexibility in selecting suitable farming practices. As an example, Participant E believed that because much of her farm was on lighter, sandier soils, AMP grazing would not suit her farming system.

> I think every farmer and every farm is different and you're never going to say, this is the way you should farm one hundred percent, because, you know, everyone's different (Participant E).

Further examples of farmers' tailoring their systems to their environment were provided. Participant A explained that their farm previously had fields in cereal production. This was something they were actively challenging, basing their land use decision on what suits best their Highland environment, as opposed to what had been done previously. Of importance in designing a context-specific farming system was understanding the unique land capabilities of the farm. Participant H explicitly viewed their farm as a system to be kept "in balance" if it was to be sustainable.

Participants also discussed the tailoring of their approaches to their environment with consideration of the rate of farming change. Participants A and B referred to the concept of "maximal sustainable output" (MSO), which they were looking to achieve, albeit cautiously. This is the point at which they could maximise their farm output without having to increase their dependence on external inputs, and is therefore a metric that combines financial and environmental objectives. The participants acknowledged that farming in this way was a process that would take time as they brought about changes to their soils and the wider agroecosystem. Further, Participant E described the gradual process of selectively breeding a herd adapted to her desired grass-based system. The desired results take time, a factor which – if unrecognised – may put farmers off transitions to lower-input systems.

> It took 10 years, and people that just say "oh, you know overnight I'll just turn to grass". There'll be a lot of herds that will not fatten on grass, then they'll suddenly think the system is rubbish (Participant E).

While participants were tailoring their management to the farm, those farms that were transitioning from conventional systems were designing approaches aligned with their previous capabilities. Learning was key for change, but farmers were not radically overhauling their farm types – dairies remained dairies etc.

> We've got to do what suits our system… ultimately, we're growing cereals, so we need to get our wheat in the ground… Wheat's our cash crop (Participant J).

The size of the farm also influenced farmers' practices. Most notably, market gardens operated on very small scales and so relied on manual labour. Several smaller livestock farms (Participants A, F, and H) also primarily relied on manual labour – the daily moves required of AMP grazing could be managed on foot with electric fencing. In contrast, larger scale farms were heavily dependent on mechanisation.

Scale seemed to also influence involvement in alternative food networks. While most participants were engaged in direct sales (11/15), it appeared more important for the financial viability of smaller farms. However, this was also clearly influenced by what the farm was producing: arable enterprises producing commodity crops did not lend themselves to selling directly to consumers. Nevertheless, selling directly was clearly more than a factor of scale – it was also a reflection of participants' personal values and objectives.

2.4.4. Reflecting personal values

Participants discussed concern for the environment, dissatisfaction with the current food system, and the desire to be autonomous. To varying degrees, their farming approaches were a translation of these values into practice. Many of the practices they were implementing were not only justified in terms of their financial benefit, but also in terms of the contributions to their wider value-driven objectives. For example, there appeared to be synergies – win-wins – between some environmental and economic objectives.

> It was just to cut costs and to make every enterprise pay. It was only after we kind of started the journey that we were like, ah, there's actually a million other benefits (Participant E).

Direct drilling was perceived to have a lower carbon footprint when compared with plough-based systems due to fuel savings and potential benefit from the capacity of the soil to act as a carbon sink (Lal, 2004), and saved farmers money on fuel and labour. Participant H spoke of the grassland productivity and biodiversity benefits of AMP grazing. Participant A, who was selling directly, discussed how their communication with customers about the way in which they were supporting local ecosystems translated into effective marketing of their produce. In such examples, it appeared that the practices perceived to result in environmental benefits were at least in part enabled by their positive financial outcomes.

Direct sales also facilitated synergies between objectives. Participants expressed frustration with the current food system, and this appeared to be influential in their decisions to sell directly to consumers. In doing so, they were able to retain a greater share of the profits – having cut out supply chain intermediaries – and also contribute to environmental and social goals by supplying their communities with local, sustainably produced food. Direct selling could therefore be an attractive business model, especially for smaller-scale producers, but it was also a means of translating farmers' values into practice.

Win-wins were of course desirable for all farmers, and Participants A, D, and F discussed a holistic decision-support framework that they used to identify such options. The framework considered the social, environmental, and economic implications of farm management decisions. In general, though, farmers revealed that they were more frequently required to make trade-offs between their objectives than they were able to realise synergies. It appeared that

win-wins could carry agroecological approaches so far by, for example, improving the efficiency of the farm. However, for those farms actualising a more transformative approach, objectives were often in competition. In such cases, the holistic management framework is useful for considering the economic, environmental, and social trade-offs of any decisions.

Some farmers were willing to sacrifice profit for competing objectives, indicating that this approach to farming is not simply about maximising income. Several examples were given of farmers' balancing of economic outcomes with environmental goals. Participant A, livestock farmers, discussed limiting stock numbers to increase on-farm species diversity. Participant B, a mixed farmer, described having to trade-off different farm management practices: no-till drilling crops may maintain soil structure, which the farmer associated with positive environmental outcomes, but yields will likely suffer in comparison with a plough-based system. Participant C acknowledged that his sparing use of pesticides and minimal soil disturbance had likely come at the expense of some profit over his career – a trade-off he was happy to make due to his perception that he was building a more resilient farm.

Participants also described the adverse impacts that incorporating social objectives into their businesses could have on profitability. Participant E explained that she passed up an opportunity to increase profits through her farm shop during the COVID-19 lockdown because she was unwilling to sell beef that she perceived as inferior quality or that was produced to lower environmental standards.

> I think, possibly if I threw all of my morals out of the window, we could have made quite a lot of money (Participant E).

Several other farmers discussed the conflict between their social justice and economic objectives. Participant I, market gardeners, described that their priority objective was to pay themselves a fair wage, as their business could not yet support them both fulltime. Despite this, a competing objective of feeding their local communities led them to make decisions that were not profit-maximising.

> Yeah, like micro greens. I mean really, from an economic perspective, we should really do that. But I don't want to (Participant I).

Participants A and F were also adamant that their businesses should provide food locally, even if there were opportunities to sell more widely across the UK. As well an providing an income, their produce was a means of building resilience in local communities.

> We keep the radius in which we sell beef to as small as possible really (Participant A).

Market gardeners K, L, and I also emphasised the integral role that engaging with local communities played in motivating their approaches. Participant L stated that the small, intimate, and local nature of his business was a core reason for him enjoying his work so much, and so he had no desire to scale up production.

Therefore, in some instances, the principles and practices of agroecology could be applied by farmers to put the farm on a better financial footing, but in others, they were applied at a financial cost. A temporal dimension is relevant in such decision making, in that decisions that were not profitable in the short-term were perceived in some case to be an investment in long-term income security – for example, investing in soil health. Nevertheless, it was clear that, for most participants, their actualisations of agroecology were not exclusively economically driven. Farming was a means of translating their personal values into practice, often at the expense of profitability. It was notable that such value-driven decisions were frequently made by smaller-scale producers, who appeared to face the greatest challenges in running profitable businesses. Participant F, farming on approximately 30 hectares, described how his business was not yet able to fully support a couple financially, but this was his aspiration. Participant L, a market gardener, spoke of both the financial hardship in establishing his business, and the additional training he was undergoing as a counsellor to diversify his income. Participants A and I both worked part-time elsewhere. These producers were designing approaches that placed the environment and community on at least equal footing with their own profitability.

2.5. Discussion

This study has aimed to capture the essence of agroecological farming as actualised in Scotland. In doing so, agroecology was found to be a value-driven approach to developing individualised, lower-input farming systems. This discussion considers the intended impacts of this approach on both agroecosystem and food system transformation.

Participants emphasised the role of ecological principles in shaping the design of their farming systems, and the impacts of these on the agroecosystem varied. The application of ecological

principles was contextualised by farmers with reference to soil health: well-managed soil may facilitate productive farming systems with enhanced functional biodiversity and reduced dependence on synthetic inputs (Hawes, Iannetta, & Squire, 2021). This can improve farm profitability through cost savings. The actualisation of such systems was therefore perceived to be predicated on the transformation of soils. However, several of the practices being implemented by farmers for the attainment of this goal also had implications for wider on-farm agroecosystem change. For example, Participants A, H and O, all of whom were livestock farmers, had designed grazing strategies based on grassland rest and recovery. The accompanying result of this was the repopulation of native grassland species and improved on-farm biodiversity. Additionally, cover crops, integrated or trialled by several participants (B, C, E, G, and J), built soil fertility while also providing food and habitat for wildlife. Aiming to realise the soil health benefits of mixed farming systems, Participant E had also integrated sheep into her farming operation. However, emphasis on such ecological practices could align with any agroecological narrative. Rivera-Ferre (2018) found evidence of a more complex discourse than the "conforming" and "transformative" split outlined by Levidow (2014). Five distinct political narratives were identified from an analysis of documents published by organisations and governments around the globe advocating for agroecology: agricultural development; performance; natural resource; climate change and food security; ecosystem's ecological management; and people's and women solidarity. Participants were intentionally attempting to bring about agroecosystem change, but the extent of transformation requires consideration also of their wider farming objectives.

Other ecological practices appeared to be less contributory to agroecosystem change. Among arable farmers, direct drilling was widely implemented. For clarity, this is distinct from no-till drilling, which is cultivation-free. Two of the farmers interviewed no-till drilled part of their farm, but explained that this results in a yield reduction. Farmers utilising direct drilling with a minimum cultivation drill, however, were achieving comparable yields with their previous plough-based systems and benefiting from the cost savings. This practice can benefit soils by maintaining soil structure and preventing erosion consequent of exposed soils. However, farmers direct drilling were still doing so in monoculture systems, the redesign of which could be considered a fundamental aspect of transformative agroecology (Miguel A Altieri et al., 2017). Further, interviews found little evidence to suggest that the monoculture model was being meaningfully challenged. Companion cropping was discussed by Participant J, but this was not at the time a widely integrated practice. Notably, such an objective lacks a clear

economic incentive. This contrasts with the outlined soil health building practices, which may result in cost savings on fertilisers, pesticides, chemicals, and labour, and some of which are incentivised through agri-environmental government support schemes.

The extent of agroecosystem redesign therefore appeared to be practice dependent. However, understanding the longer-term impacts of these practices and their implications for agroecosystem change is challenging. It is necessary to understand how such systems are best evaluated, given their complexity (Hawes et al., 2021). Various approaches have been developed, including whole systems sustainability (Hawes et al., 2019), resilience and adaptability (Tittonell, 2020), and participatory assessments (Dumont et al., 2021).

Notably, farmers used terms in addition to agroecological to describe their approaches (Table 5). Some of the participants farmed organically and/or identified with the term regenerative agriculture. Two dairy farms labelled their systems specifically as "cow with calf", as calves spent the first six months of their lives with their mothers, in contrast to conventional systems in which cows may be separated from their calves within hours. All three of the market gardeners interviewed also referred to the practices and principles of permaculture, and two were CSA models. One of the benefits of agroecology as a concept appears to be that it brings together other alternative agriculture approaches into a common group. The principles are now well-defined but sufficiently flexible to be implemented at least partially in a range of different farming systems, from larger farms to small scale market gardens.

Agroecosystem redesign is only one objective of transformative agroecology; it also has an integral social dimension (Wezel et al., 2020). This is centred on the development of a socially just food system through the provision of healthy, affordable, and culturally appropriate food. Most of the participants were aiming to directly influence food system change of this kind, primarily by engaging in direct sales. Even those farms not engaged in alternative food networks had a significant social dimension inherent in their approach, through their involvement in knowledge exchange activities. However, an objective of contributing to food system change appeared necessary for more transformative actualisations of agroecology. Participants engaged in direct sales were motivated to feed their local communities, and viewed their produce as high quality and sustainable. Farmers have several sales mechanisms to choose from, including farm shops, online orders, CSA, vending machines, and food hubs. Each participant's chosen approach was context dependent – there was no standard model by which farms were contributing to the development of alternative food networks. Direct sales

facilitated close relationships between farmers and consumers, which was important both in informing the farming approach and in providing farmers with job satisfaction through positive feedback.

A recognised challenge of this approach to food system transformation was the affordability of agroecologically produced food. Participant H aspired to make her produce available to lower income households, but viewed this as a current challenge. Two market gardens had introduced a sliding scale payment mechanism intended to address issues of affordability: individuals who were able to pay above the set price of the vegetable box scheme could do so, with their additional payment subsidising the price for another customer who otherwise could not afford to sign up to the scheme.

Further, direct selling puts significant demands on the farmer to develop the skills and systems to run their business in this way. Farmers were not only having to learn how to apply ecological principles on their farms, but also how to integrate their businesses within alternative food networks. Their role is no longer limited to food production, but also the marketing and distribution of their produce.

A limitation of this study is that we have explored only the experiences of agroecological farmers, and not a broader range of food system actors that hold influence over agroecological transition in Scotland, including policymakers, agribusiness, retailers, and consumers. While we have demonstrated that, at a farm level, agroecology appears to be conceptualised in a transformative sense in that farmers are aiming at both agroecosystem and wider food system change, this alone is not sufficient to bring about meaningful change. Schiller and co-authors (2020) outline that in Nicaragua, where an agroecology movement has been developing since the 1980s, present-day food system change is hindered by a lack of government commitment to agroecology. A hybrid approach that aims to support all forms of agriculture undermines the agroecological movement. The Scottish Government, who are in a period of agricultural policy redesign following Brexit, ought to learn from this. Research into agroecological farming was highlighted in their *First Steps toward Our National Policy* following a 2021 consultation (Scottish Government, 2021a). This may either signal the beginning of institutional adoption or institutional co-optation of agroecology in Scotland, and further research is needed to explore this issue.

The extent of transformation at both an agroecosystem and food system level varied on each farm and was clearly tied to each participant's need to run a profitable business. The profitability of agroecological systems compared with conventional systems appears to be a complex relationship to unpick and requires consideration of unique farming context. Participants D, E and M described economic pressures that had prompted a shift towards agroecology. Conversely, Participant C, who had been orienting his farm towards agroecology for over 20 years, believed that he had traded profit for farm resilience over the course of his career. Padel and co-authors (2020) identified a number of such "trigger events" that had prompted UK farmers' agroecological transitions, including financial struggles, farm succession, training events, and concerns over soil fertility.

It was evident that many of the smaller-scale farmers (Participants A, F, I, L, and N) did not generate sufficient income from their farm produce to support them full-time. These farmers had employment elsewhere or had established alternative income streams. For example, Participant A had a part-time research position, Participant N produced an income-generating vlog, and Participant L was training to be a counsellor. Importantly, smaller-scale farms of this kind appear to be the most authentic actualisations of agroecology. Transformative agroecology does, after all, place emphasis on small-scale and peasant farming (Giraldo & Rosset, 2018; Wezel et al., 2020). These farms have minimal dependence on fossil fuels, they are circular and diverse, and they support local, rural communities. In contrast, the larger-scale farms were limited in their agroecological actualisations in that they were dependent on the monoculture model, and some were not engaged in alternative food networks. These actualisations are clearly distinct from the transformative agroecological "ideal" described in literature (Dumont et al., 2021), defined as the implementation of each of the ecological and socioeconomic principles of agroecology.

Most participants were clear in outlining both environmental and social justice objectives in their farming approach. The extent to which they were able to realise these objectives depended on their unique context or, alternatively stated, their stage of agroecological transition. This suggests that, in the main, farmers' conceptualisations of agroecology matched a transformative narrative, even if they were unable to bring this vision fully into practice. As such, for the majority of participants, their approach extends beyond an efficiency-driven agroecological narrative by also incorporating objectives relating to food sovereignty through their engagement in short food supply chains (Rivera-Ferre, 2018). However, two participants

did explain that there was no motivation for them to engage in alternative food networks. They expressed values relating to the environment long-term condition of the farm, and were primarily aiming for a shift to more efficient systems with lower dependence on external inputs.

There may be questions surrounding the capacity of small-scale producers to play a leading role in Scotland's agricultural transition. However, this study did find an example of a more scalable approach to transformation. Participant D, a dairy farmer, established a co-operative with neighbouring dairy farmers that produce their milk to the same environmental standards. Participant D processes the milk of each of the co-operative members at his dairy and, as well as selling directly to the public, has been awarded a contract to supply the local council and school with milk. Co-operatives may therefore be an important mechanism that enables the scaling up of agroecologically produced food (Nicholls & Altieri, 2018; Rosset, Machín Sosa, Roque Jaime, & Ávila Lozano, 2011; Van Der Ploeg, 2021).

Finally, as with agroecosystem impacts, suitable tools are required to measure and understand the impacts of agroecology on the food system. For example, most participants were contributing to the development of local food systems. Recent research has highlighted that dietary shifts to more plant-based foods in affluent countries to reduce food system greenhouse gas (GHG) emissions should be accompanied by a shift to local food consumption given the significant contribution of food-miles to overall emissions (Li et al., 2022). It is necessary to quantify the impacts of Scottish farmers' agroecological transitions on food-miles and their associated emissions. Additionally, it is important to recognise that GHG emissions are only one facet of environmental sustainability. As well as the environmental impacts, it is important to understand the health and wellbeing impacts of transitions to agroecology. Agroecologically produced food tends to be unprocessed or minimally processed. The recent *National Food Strategy* report in the UK highlighted the link between ultra-processed foods and dietary induced diseases (Dimbleby, 2021). By engaging in food networks where such food is either absent or far less abundant, consumers may be guided to healthier eating habits. Local food networks also provide the opportunity to develop positive relationships between farmers and consumers. Not only can this have wellbeing benefits for farmers, but close contact means that consumers are informed on where their food comes from, and farmers can build consumer feedback into their production systems.

2.6. Conclusion

The findings suggest that farmers' actualisations of agroecology in Scotland are broadly aligned with a transformative agroecological narrative (Dumont et al., 2021; Rivera-Ferre, 2018; Wezel et al., 2020). There is a clear value-driven dimension of participants' approaches that aligns with a transformative vision of Scotland's farming and food systems. Efficiency gains and cost savings were important, but not the only objectives, and were being practically implemented through a range of agroecological practices, including cover cropping, reduced tillage, livestock integration, AMP grazing, and silvopasture. Moreover, most of the farms were engaged in alternative food networks, most notably the smaller scale producers. Nevertheless, there also appear to be conceptualisations of agroecology that are linked to sustainable intensification, but lack direct social justice objectives. Great care is required in communicating this issue in farming spheres, in order not to alienate those that hold "conforming" conceptualisations of agroecology (Levidow et al., 2014). Farmers alone cannot bear full responsibility for agroecological transition, and it is understandable many may not look past the farm-level.

Farmers' experiences have also revealed a mindset associated with the sustainable farming movement, having indicated both an attitude of working with nature, and a willingness to learn (Kretschmer, Langfeldt, Herzig, & Krikser, 2021; Padel et al., 2020; Rodriguez, Molnar, Fazio, Sydnor, & Lowe, 2009). Farmers described working with their soils, and nature more widely, in the development of their systems. This is already a recognised mindset within market gardening as it is at the heart of permaculture design (Whitefield, 2004). Agroecology, however, appears to be a vehicle for bringing these ideas to a larger audience. Future work could compare this mindset with that of conventional farmers to understand the differences more fully.

This study has been specifically interested in exploring the contribution of farmers to agroecological transition in Scotland. Nevertheless, a limitation of this research is that only the experiences of farmers have been considered. While the farm-level narrative suggests Scotland's agroecological farmers generally hold transformative aspirations, further research ought to explore the perspective of actors across the wider food system. Secondly, based on the approaches of the study participants, involvement in alternative food networks was considered as the primary contribution to food system change. Individuals and organisations

involved in Scotland's agroecological movement may also be striving for reform of the dominant industrial food system, and further work could consider these contributions.

Finally, individuals farming on smaller scales emphasised more greatly their economic challenges. Such farms appear to be actualising agroecology in its most transformative form. Therefore, a recommendation for policymakers is to explore the mechanisms through which smaller-scale producers can be supported in their operations. Brexit, and the ensuing re-evaluation of agricultural policy perhaps presents such an opportunity.

Chapter 3. Critical Systems Heuristics: A Systematic Review

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3.1. Overview

CSH has been significant in shaping the critical systems thinking tradition. However, it is a relatively underutilised method compared with soft systems approaches such as SSM and cognitive mapping. This may in part be due to the complexity of ideas underpinning CSH. Core ideas with which users must feel confident include boundary critique, coercion, emancipation, and "is" vs "ought" framings. These ideas were debated in the early discourse surrounding CSH, which considered the role of boundary critique in systems research, the extent to which CSH could meaningfully address coercion, and the claims of CSH as an emancipatory approach. The purpose of this review is to provide clarity on these key concepts by reflecting on how they have been addressed in the CSH literature to date. We find that CSH has been applied in a range of problem contexts and is most frequently applied to address coercion or power asymmetries. CSH research is frequently associated with advocacy for marginalised groups, and we believe this is a natural extension of the methodological emancipation to which CSH aspires. In providing an overview of the key ideas underpinning CSH, we hope to lower the barrier to application for systems researchers and practitioners.

3.2. Introduction

While soft systems approaches such as SSM and cognitive mapping offer mechanisms for *capturing* different perspectives on complex issues, critical systems thinking emphasises *reflecting* on these systems of thought. Werner Ulrich's CSH has been influential in shaping the critical systems thinking tradition and is a framework that facilitates such reflection (Midgley, 1997a; W. Ulrich & Reynolds, 2010). The rationale for the critical approach is that understanding of true reality is limited – we will always fall short, but to remain close we must engage in a process of continual reflection on the judgements and assumptions that shape our understanding (W. Ulrich, 2003). Accordingly, Ulrich outlined a framework for learning about problematic situations through critical reflection on our conceptual mental models (Table 6).

The CSH framework is organised as four boundary categories, each comprised of 3 boundary questions (W. Ulrich & Reynolds, 2010). The categories are motivation, control, knowledge, and legitimacy, and their associated boundary questions are designed to uncover what is and what is not relevant to the system of interest. Further, each boundary question may be asked in both the "is" and "ought to be" modes, offering another dimension to the framework as users can explore the system as it is now, and as it would be ideally.

Table 6. CSH framework (following Ulrich & Reynolds, 2010)

Sources of Influence	**Boundary Questions**	
Sources of Motivation	Beneficiary	13. Who ought to be/is the intended beneficiary of the system?
	Purpose	14. What ought to be/is the purpose of the system?
	Measure of Improvement	15. What ought to be/is the system's measure of success?
Sources of Control	Decision Maker	16. Who ought to be/is in control of the conditions of success of the system?

Sources of Influence	Boundary Questions	
	Resources	17. What conditions of success ought to be/are under the control of the system?
	Decision Environment	18. What conditions of success ought to be/are outside the control of the decision maker?
Sources of Knowledge	Expert	19. Who ought to be/is providing relevant knowledge and skills for the system?
	Expertise	20. What ought to be/are relevant new knowledge and skills for the system?
	Guarantor	21. What ought to be/are regarded as assurances of successful implementation?
Sources of Legitimacy	Witness	22. Who ought to be/ is representing the interests of those negatively affected by but not involved with the system?
	Emancipation	23. What ought to be/are the opportunities for the interests of those negatively affected to have expression and freedom from the worldview of the system?

Sources of Influence	Boundary Questions	
	Worldview	24. What space ought to be/is available for reconciling differing worldviews regarding the system among those involved and affected?

Since its inception, the positioning of CSH research and practice within the systems thinking tradition has been the subject of debate. While Ulrich suggests that his approach ought to fundamentally revise our mode of inquiry in systems research (W. Ulrich, 2003), other authors have suggested that the contributions of CSH – while important in the development of systems thinking – are more circumscribed (Jackson, 1985; Ormerod, 2004), and regard CSH as a methodology for addressing specifically coercive problem contexts. This debate surrounding suitable application of CSH may have contributed to the relative underutilisation of a method that already contains an array of complex ideas with which users must build familiarity. A Scopus search for "Critical Systems Heuristics" for this review returned a list of 107 documents, 77 of which met the criteria for this review. Similar searches for "Soft Systems Methodology" and "Cognitive Mapping" returned 1,250 and 2,289 documents, respectively. It is of interest to consider why CSH, which formally integrated critical inquiry with the systems thinking tradition (Midgley, 1997a), has not been more widely utilised in systems research and practice.

As far as we are aware, there has not yet been a systematic review of CSH research since its development. As a result, we believe that it is important to reflect on CSH research and practice, to understand how it has been shaped by early discourse surrounding the framework. This review explores how CSH has been applied, and does so with reference to key CSH terminologies, namely: coercion, emancipation, boundary critique, "is" vs "ought", and specifically considers CSH in an action research context. In exploring the way in which researchers have applied the framework, the review aims to provide clarity around key CSH concepts.

3.3. Methodology

Studies for this review were obtained by searching the Scopus database using the search term "Critical Systems Heuristics". This returned 111 documents, which were filtered to include only peer reviewed articles and reviews, and exclude conference papers and duplicates. The remaining 77 papers were then reviewed, with an aim of understanding how key CSH concepts have been addressed. With this purpose, we have structured the review around important CSH terminologies. By taking this approach, we aim to provide clarity on these key ideas with a view of supporting future CSH research and practice. The review first provides an overview of the problem contexts in which CSH has been applied. We then consider the early discourse surrounding the methodological positioning of CSH in systems research, laying the foundation for the remainder of the review, which is organised into sections on coercion, emancipation, boundary critique, "is" vs "ought", and action research.

3.4. Problem Contexts

CSH has been applied in a diverse range of problem contexts, summarised in Table 7. The largest body of CSH research is in education: Goede and Taylor used CSH to support the development of an information systems university module that would leave students better equipped to make the transition into industry (Goede & Taylor, 2019; Taylor & Goede, 2016); separate studies have applied CSH in interventions designed to improve students' programming skills (Manduna, Goede, & Drevin, 2022; van der Linde & Goede, 2021); and Algraini and McIntyre-Mills (2018) explored challenges to students' development in Saudi education. Further, Raza (2021) addressed a problem of educational timetabling, and Houston and Paewai (2013) and Luckett (2006) explored the more specific issue of quality assurance in higher education. CSH appears well-aligned to address problems in education as one of the core features of the methodology is the provision of a platform for groups or individuals that may not otherwise have the opportunity to express their views on a situation by which they are directly impacted. The CSH framework can therefore be used to guide students' involvement in the design and improvement of their learning experiences, an opportunity that they may not usually be afforded.

Several studies have applied CSH to explore problems in agriculture. The specific issues investigated relate to GM crops (Carr & Levidow, 2000; E. Tavella, 2016), rice supply chain

sustainability (Elyasi & Teimoury, 2023), agroecological transition (Hutcheson, Morton, & Blair, 2023), and Indonesian beef farming (Setianto et al., 2014). Complexity arising from environmental challenges, multiple stakeholders across the supply chain, and technological innovation means such issues in agriculture are challenging to unpack and as such are well suited to exploration with CSH. Other notable areas in which multiple CSH studies have been conducted include health (Buse, 2013; Gadsby, Wistow, & Billings, 2022; O'Hara & Taylor, 2023; Elena Tavella, 2023), public services (Flood & Jackson, 1991; Johnstone & Tate, 2017; Levin, Gewirtz, & Cribb, 2017; Torun & Torlak, 2022), intervention design and evaluation (Hart & Paucar-Caceres, 2014; Midgley, 1997b; Ormerod, 1997; Parrilla & Neyra Belderrain, 2023), and technology (Donaires, 2006; Duboc, McCord, Becker, & Ahmed, 2020; Loveridge & Saritas, 2009; Syed Arshad Raza, Siddiqui, & Standing, 2019). Finally, several of the papers reviewed are not practical applications of the framework but contributions to theoretical and methodological discussions about CSH (Jackson, 2001, 2005; Midgley, 1997a; Ormerod, 2004; Romm, 1995; W. Ulrich, 1993, 2001, 2003, 2004, 2012a, 2012b).

Table 7. Problem contexts in which CSH has been applied.

Problem Context	**Examples**
Agriculture	(Carr & Levidow, 2000; Elyasi & Teimoury, 2023; Hutcheson et al., 2023; Setianto et al., 2014; E. Tavella, 2016)
Art conservation	(García Celma, 2021)
Banking	(Dehghan Nayeri, Khazaei, & Alinasab-Imani, 2020)
Business intelligence systems	(Venter, 2019; Venter & Goede, 2017, 2018)
Public Services	(Flood & Jackson, 1991; Johnstone & Tate, 2017; Levin et al., 2017; Torun & Torlak, 2022)
Child care and protection	(Ariyadasa & McIntyre-Mills, 2015; Chowdhury, Gregory, & Queah, 2023; Fitch, 2012)
Co-creative research	(Nicholas et al., 2019)

Problem Context	**Examples**
Environment	(Cleland & Wyborn, 2010; Klocker Larsen, 2011; Lyons-White, Mikolo Yobo, Ewers, & Knight, 2022)
Energy	(Sianipar, Chao, & Hoshino, 2023; Sunitiyoso, Mahardi, Anggoro, & Wicaksono, 2020)
Community development	(Pinzon-Salcedo & Torres-Cuello, 2018; Riswanda, McIntyre-Mills, & Corcoran-Nantes, 2017; P. Tirivanhu, Matondi, & Sun, 2016)
Corporate social responsibility	(Reynolds, 2008; Vos, 2003; Zlatanović, 2015)
Education	(Algraini & McIntyre-Mills, 2018; Goede & Taylor, 2019; Houston & Foote, 2001; Kish et al., 2021; Manduna et al., 2022; Taylor & Goede, 2016; van der Linde & Goede, 2021)
Enterprise resource planning	(Mirhosseini, Ramezani, Khazaei, & Azar, 2021)
Evaluation	(Gates, 2018; Gregory, 1997; Precious Tirivanhu, 2022)
Health	(Buse, 2013; Gadsby et al., 2022; O'Hara & Taylor, 2023; Elena Tavella, 2023)
Intervention design and evaluation	(Hart & Paucar-Caceres, 2014; Midgley, 1997b; Ormerod, 1997; Parrilla & Neyra Belderrain, 2023)
MSEs	(Donaires, Pinheiro, Cezarino, Ostanel, & Martinelli, 2010)
Theoretical contributions and discussion	(Jackson, 2001, 2005; Midgley, 1997a; Ormerod, 2004; Romm, 1995; W. Ulrich, 1993, 2001, 2003, 2004, 2012a, 2012b)

Problem Context	Examples
Organisational conflict management	(S. A. Raza & Standing, 2011)
Performance assessment and auditing	(Irawan & McIntyre-Mills, 2016; Mejía, Mariño, & Molina, 2019)
Quality assurance	(Houston & Paewai, 2013; Luckett, 2006)
Sustainable development	(Maru & Woodford, 2001; Reynolds, 2014)
System complexity	(Valentinov, 2012)
Technology	(Donaires, 2006; Duboc et al., 2020; Loveridge & Saritas, 2009; Syed Arshad Raza et al., 2019)
Timetabling and planning	(Jeppesen, 2011; Leleur, 2004; S. A. Raza, 2021)
Water governance and management	(Simbolon, 2017; Wallis, Ison, & Samson, 2013)

3.5. Methodological Positioning

A key tenet of the early discourse surrounding CSH its methodological positioning. One critique of CSH has been its supposed rejection of methodological pluralism (Midgley, 1997a). The case for methodological pluralism in systems research is outlined most notably by Jackson and Keys (1984) in their proposed system of systems methodologies. They make the point that real-world problems can be categorised into different problem types based on the levels of complexity and agreement inherent in the problem situation, and that the type of problem influences the most suitable methodological choice. Mechanistic problems are simpler and may be solved by applying traditional, hard OR methodologies, while systemic problems are more complex and are suitable to more recent systems methodologies, such as system dynamics. The level of agreement in the problem situation also influences methodological choice – problems in which there is no divergence of opinion on the nature of the problem – two such categories

outlined by Jackson and Keys are mechanistic-unitary or systemic-unitary problems – may be more easily modelled and solved. However, many managerial problems are made more complex owing to different perspectives on the nature of the problem. Such problems are pluralist and require “soft” methodologies capable of capturing and addressing different perspectives on a problem. Ulrich appears to take issue in general with systems science methodologies, citing their inherent lack of critical reflection.

> Policy analysis and program evaluation show an amazing helplessness, if not indifference, with respect to the problem of value judgments. Both pursue the same goal of applying science to public decision making so as to secure improvement, but neither has developed convincing heuristic tools for identifying and rationally unfolding the normative content of any concept of improvement, definition of "the problem," or solution proposal (Werner Ulrich, 1988).

As a result, Ulrich takes the view that the principles of CSH ought to permeate through all systems methodologies applied to social systems, rather than tying the framework to any specific problem type. Critics view this as a harsh assessment of systems science. Jackson (1985) noted that successful interventions do not necessarily require adequate modelling of the “purposeful social systems” with which Ulrich is concerned. We should not lose sight of what is viable and useful in any given problem context.

CSH has not resonated with sufficiently many people to result in an overhaul of systems methodologies (Ormerod, 2004). Nevertheless, many systems researchers and practitioners instead turned towards CSH as a means of addressing a specific issue that was inadequately addressed by existing systems methodologies – coercion.

3.6. Coercion and Power Asymmetry

Coercion can be defined as the application of force or pressure to groups or individuals so that they engage in behaviours that they either do not want to or are not in their best interests. It is a key issue in situations with power asymmetries between stakeholders and one which CSH aims to address. As such, several studies have applied CSH to problems involving marginalised groups or individuals. Examples include Ariyadasa and McIntyre-Mills' (2015) examination of the governance determining the experiences of Sri Lankan children in institutional care, Riswanda and co-authors’ (2017) advocacy for the involvement of individuals adversely

impacted by prostitution in Indonesia in policymaking on this issue, and Cleland and Wyborn's (2010) engagement with a deprived fishing community in the Philippines in exploring coral reef management.

Other soft OR approaches outline mechanisms for capturing different perspectives on management issues, but CSH is unique in that it defines a mechanism for better understanding and addressing power dynamics, and for considering individuals and groups adversely impacted. Tirivanhu and co-authors (2016) apply CSH because of its ability to address power relations in multi-stakeholder problems, and use it to evaluate a community self-development initiative in Zimbabwe. Kish and co-authors (2021) chose to explore the Journal of Ecological Economics using CSH, having recognised the power it holds over which research is published and the resulting influence this has on shaping the direction of the field. Moreover, Maru and co-authors (2001) propose that CSH may usefully inform the design of interventions in sustainable development initiatives, despite the asymmetrical relationships present in such problem contexts.

Further CSH applications include the enhancement of teaching programmes (Algraini & McIntyre-Mills, 2018; Goede & Taylor, 2019; Manduna et al., 2022; Taylor & Goede, 2016; van der Linde & Goede, 2021), the development of business intelligence systems (Venter, 2019; Venter & Goede, 2017, 2018), and building understanding in research practice (Nicholas et al., 2019). These problem contexts are not overtly coercive, however, power dynamics, and conflicting understandings and interests do play an influential role: students and teachers have different roles and levels of control in the learning environment; different stakeholders may have multiple and conflicting requirements of a business intelligence system; researchers and practitioners may understand and interpret differently an emerging area of research. In all such cases, there is the potential for some perspectives to be more dominant at the exclusion of others. CSH provides a platform for different perspectives to be expressed with a view of surfacing adverse impacts on different individuals and groups.

An issue here appears to be in the language that is used. It is easy to understand how the examples of institutional care for children, human rights and prostitution, and coral reef management in deprived communities are inherently coercive problematic situations following our earlier definition. But following Ulrich's (2003) definition of coercion – "structural conditions that create an asymmetry of discursive chances" – the latter examples of education, business intelligence systems and research development may also be considered coercive.

Indeed, any management problem that involves multiple individuals and perspectives has the potential to meet this definition of coercive.

> It is clear that in real-world discourses, such conditions of structural inequality are the rule rather than the exception (W. Ulrich, 2003).

Clearly, the potential for asymmetric discursive chances is present in any management problem. By this definition, it does not appear helpful to refer to coercive and non-coercive problems. We might instead think of CSH as a framework for exploring and navigating the coercion inherent in management problems, which may be present in greater or lesser extents. This only requires a slight re-framing of commonly held understandings of why the framework is applied: it is not an approach for exploring coercive problems, rather, an approach that, in part, explores the influence of asymmetric power relations in management problems.

Of course, other definitions of coercion exist. Midgley defines it as the "closure of debate" (Midgley, 1997a) and highlights valid questions regarding the effectiveness of CSH as an approach for addressing coercive problems following this definition. CSH is incapable of addressing such situations since the methodology is predicated on reflective debate between stakeholders i.e coercive problems are absent of reflective debate, and without the opportunity for reflective debate, CSH is not possible (Midgley, 1997a). Midgley therefore advocates for the inclusion of political action and campaigning – change oriented activities - in interventions aimed at emancipatory outcomes.

We believe that a practical take on the extent to which CSH can address coercive problems is provided by Luckett (2006), who applied CSH to explore perspectives on policies for quality assurance in South African higher education. While this study demonstrated the utility of CSH for aiding policymaking in that the findings influenced the final design of policy instruments, Luckett recognised that CSH was limited by the coercive problem context in which it is applied, and so is cautious about the extent to which issues of power and control are addressed by the framework, citing the dominant influence of a young democracy on policy. Therefore, while CSH may be a useful tool for exploring coercive problem contexts, this does not mean that it is always effective in transcending power dynamics in the delivery of socially rational outcomes.

While CSH alone may be insufficient in uncovering the cause-and-effect relationships that underpin coercive problems, simply by directly structuring interventions and research around

the mapping of control and legitimacy, CSH surpasses soft systems frameworks in its potential to provide insights into coercive problems. This points towards the integration of CSH and methods that are better suited to uncovering cause and effect relationships. An example is provided by Setianto and co-authors' (2014) investigation of smallholder beef farming in Indonesia using a multimethod approach that incorporates SSM, CSH, and causal loop diagrams. CSH was used in addition to SSM specifically to address asymmetric power relations. This was deemed important given the lack of power that farmers have in the Indonesian food system. CSH was applied to build a comprehensive understanding of the problem in the form of a conceptual model, which was followed by causal loop mapping to identify leverage points for change.

There is clearly a question over the extent to which CSH interventions can meaningfully impact change in significantly coercive contexts, such as those dominated by corruption or authoritarianism. Nevertheless, we believe that the first steps in achieving emancipation in such contexts is by striving to illuminate these destructive dynamics. CSH achieves this not only by directly addressing control or power, but also by considering impacts on the "affected".

3.7. Emancipation

Emancipation is associated with liberation and freedom, particularly of marginalised groups or individuals, and research objectives of this kind are evident in CSH research. For example, Ariyadasa and co-authors (2015) explore the care system for Sri Lankan children with an emancipatory purpose:

> The aim of the research is to advocate for the standard of care the children receive, and the life chances they deserve in order for them to reach their full potential and integrate into their societies when they leave the children's homes (Ariyadasa & McIntyre-Mills, 2015).

Moreover, Hart and Paucar-Caceres (2014), applying CSH to evaluate outcomes of an SSM intervention for a mining case study in Peru, highlight that harder, data-driven research requested by more powerful government and industry stakeholders risks marginalising the perspectives of community groups in future interventions. Additionally, Johnstone and co-authors (2017) report on a case study of emergency service provision with historic stakeholder conflict resulting in the marginalisation of frontline workers. Their post hoc analysis

demonstrated that CSH can be used for not only the design IT project governance, but to identify and address entrenched issues within existing governance structures. In each example, CSH is applied with a view of either improving or preventing an undesirable situation for an affected group. This is the emancipatory nature of CSH as outlined by Midgley (1997a): a structured framework for considering the problem of interest from the perspectives of "affected" groups and individuals. CSH requires those applying the framework to ask specific questions relating to the affected: who represents the interest of individuals or groups negatively affected by the problem; what are the opportunities for expression for the negatively impacted; and what space is available for reconciliation of differing worldviews of individuals or groups affected by the problem (W. Ulrich & Reynolds, 2010)? As such, a key function of CSH is to facilitate deep reflection on a problem through the lens of negatively impacted groups, and so it follows that many applications addressed issues faced by marginalised groups and communities.

However, such an ideological take on emancipation places additional requirements on researchers (W. Ulrich, 2003), and this is not the definition of the emancipation to which CSH aspires according to Ulrich. He instead describes CSH as a mechanism for achieving "methodological" emancipation.

> The "emancipatory interest" in this sense is without regard for persons; its only advocacy is in favour of a situation of undistorted communication in which all concerned parties have as equal a chance of articulating their concerns as possible (W. Ulrich, 2003).

Following this definition, emancipation may be interpretated as the provision of a platform for different voices with different perspectives to be clearly understood. Research may explore the perspectives of marginalised or exploited groups with a view of advocating for their needs and rights, and it is easy to see how such objectives might build from a foundation of methodological emancipation in practical applications. However, it is the concept of methodological emancipation that is central to CSH: the framework is ultimately a mechanism through which different perspectives may be shared and critiqued, irrespective of power and worldview. This opens the door to a much wider range of problem context than only those that are overtly coercive.

3.8. Boundary Critique

How, though, does CSH address distorted communication beyond soft systems approaches? The key to this is in the practice of boundary critique. Where SSM and cognitive mapping provide mechanisms through which we can capture and explore different perspectives, CSH employs boundary critique, a means of making transparent the assumptions that underpin these perspectives. Formally, boundary critique is defined as:

> …a systematic – reflective and discursive – effort of handling boundary judgements critically, whereby "critically" means both "self-critically" questioning one's *own* claims and "thinking for oneself" before adopting the claims of *others* (W. Ulrich & Reynolds, 2010).

Alternatively stated, in exploring, testing, and expressing our sources of selectivity, CSH aims at equal opportunity for different perspectives to be heard, understood, and evaluated. It follows that such an approach has the potential to enable richer understanding and more transparent dialogue between different stakeholders than would necessarily a soft OR approach. Therefore, no perspective on an issue is readily accepted – they are instead reflected on and questioned so that they may be more comprehensively understood.

Boundary critique is practically implemented through the 12 boundary questions. These boundary questions are structured into a framework that aims to provide transparency about the assumptions that underpin perspective on a problem. The aim is to clearly understand the perspective and why it is held. For example, we are likely to better understand a particular interpretation of the purpose of any given system (boundary question 2) from a particular perspective, if we know who the intended beneficiaries of the system are (boundary question 1) from that same perspective. Summaries of the key points surfaced through application of the CSH framework are frequently presented alongside the boundary questions to which they relate (Gadsby et al., 2022; Kish et al., 2021; Venter & Goede, 2017).

This slower, deliberate approach to understanding may be better suited to addressing the additional complexity presented by power asymmetry. For example, Venter and co-authors (2018) explored routes to improving business intelligence systems. While they outlined and appreciated the benefits of Checkland's SSM in designing such an intervention, they concluded that an immediate focus on action may inhibit the formation of effective solutions in problems

influenced by coercion. Accordingly, they advocated for approaches based on CSH owing to its perceived deeper reflection on the social dimension of such problem contexts. Similarly, Torun and Torlak (2022) advocate for CSH as a favourable alternative to SSM in coercive problem situations, owing to SSM's lack of grounding in social theory.

Reynolds (2014) applies CSH to an international development project, selecting the method because of the multistakeholder nature and complexity of the project. Reynolds draws on CSH as a "pro-equity" evaluation tool and posits that its value is not only due to its ability to capture different perspectives on a situation, but that CSH allows for critical reflection on the judgements that underpin these perspectives. Using India's Narmada project as a case study, Reynolds demonstrates the alignment of CSH with a "triple-loop learning" approach, as the boundary questions move beyond understanding what a suitable intervention is and whether this intervention would be the "right" thing to do, and also consider how we know that any given intervention is the right thing to do. Thus, CSH not only considers the ethical dimension of the problem situation, but draws on the wider problem context to understand political influence. This alignment is perhaps most evident in CSH's "legitimacy" dimension, in which participants are encouraged to reflect on the problem from the perspectives of other stakeholders and consider both their adversities and mechanisms through which they can voice issues and receive support.

While coercion and power are key focuses in the majority of CSH studies, some are less concerned with addressing these issues and emphasise more strongly the role of boundary critique in unfolding understanding of a problem. Carr and Levidow (2000) use CSH to consider the risks of GM food production in the UK. They apply CSH to jointly consider the scientific and social implications of GM crops without specific reference to coercion or power structures. Mejia and co-authors (2019) propose that CSH should be incorporated widely into the guidelines for critical thinking evaluation tests. Currently iPAL assesses individuals' ability to evaluate bias and errors of judgement, evaluate and structure arguments, evaluate the consequences of action, and deliver results. The authors argue that a key omission in this framework is assessment of individuals' abilities to evaluate different perspectives on a problem, which may be facilitated by CSH. Notably, in this context, the authors draw on CSH as a framework for exploring the judgements and underpinning assumptions shaping the understanding of different individuals. While exploring sources of power is a key dimension of CSH, the purpose of integrating CSH is not driven by the authors' desire to specifically

explore coercive problems for the achievement of the emancipation of marginalised groups. Rather, integrating the principles of boundary critique into critical thinking is outlined as good practice in general. Mirhosseini and co-authors (2021) adopted a mixed methods approach in their exploration of enterprise resource planning (ERP) systems. They structured 12 interviews with ERP experts based on CSH to understand the key associated risks, before quantitatively evaluating the significance and frequency of these risks. Again, the focus of this research is not in exploring an explicitly coercive problem or marginalised perspectives. CSH is instead employed to seek comprehensiveness in understanding expert perspectives on ERP.

3.9. "Is" vs "Ought"

CSH research to date has highlighted the multi-faceted nature of the framework. In their applications, authors may be more concerned with power or the assumptions that underpin different points of view. An additional application is for ideal mapping – consideration of the system as it "is" compared with how it "ought to be" (W. Ulrich & Reynolds, 2010). This is a core feature of the CSH methodology, but authors may emphasise it more or less in their approaches. Ideal mapping encourages participants to think about their situation or problem from a "best case scenario" – if the reality of their situation could be exactly as they like, what would it look like? Participants are then encouraged to think about the situation as it is – by contrasting these two modes, the intervention facilitates a better understanding of the specificities that give rise to the "is" falling short of the "ought to be".

Wallis and co-authors (2013) emphasise comparison of the "is" and "ought to be" modes in a water governance case study in Australia. They identified factors driving the success of community-based water management governance policies, as well as barriers to the attainment of more desirable outcomes. In this way, CSH provides an effective framework not only for unpacking complex problems, but also for understanding routes to beneficial change.

3.10. Action Research

CSH studies follow a range of methodological designs. Of the 77 reviewed papers, 12 stated that they were following an action research approach (Ariyadasa & McIntyre-Mills, 2015; Dehghan Nayeri et al., 2020; Duboc et al., 2020; Goede & Taylor, 2019; Kish et al., 2021; Pinzon-Salcedo & Torres-Cuello, 2018; Taylor & Goede, 2016; Torun & Torlak, 2022; van der Linde & Goede, 2021; Venter, 2019; Venter & Goede, 2017, 2018). Action research ultimately aspires to beneficial change in the situation of interest. It is centred on reflection and

the participation of those involved. There are therefore synergies between CSH, as a mode of reflective inquiry, and action research designs. By engaging with those involved in a problem, action research aims at deep contextual understanding and evidence-based findings. In emphasising the perspectives of not only the involved, but also the affected, research following a CSH methodology draws on perspectives that may otherwise remain unconsidered, building a more comprehensive understanding of the situation of interest.

The utility of CSH is arguably best exemplified in an action research context, where the success of an intervention is determined by the extent to which it resulted in beneficial change. Pinzon-Salcedo and co-authors (2018) report perhaps the most impactful application of CSH, in which they use the framework alongside other problem structuring methods in a multi-year social development project in Columbian schools for addressing societal violence. Their designed intervention has impacted more than one million people and has permeated beyond school impact into society more widely. The authors report that their use of CSH enabled them to move beyond understanding what interventions might bring about improvement to the situation, and to also understand the assumptions that underpin these moral judgements – encouraging the questioning of judgements that may be "taken for granted". They report that fundamental to the success of their approach was participatory reflection in the design of their intervention. The concept of "marginalisation" is addressed in their approach in two ways. Firstly, their participatory approach gave members of a marginalised community a platform to voice their perspectives and contribute to the design of an intervention that was intended to address a problem in which they were the most directly impacted. Secondly, marginalisation may refer to marginalised elements of the of the problem situation (Midgley, 1992). CSH boundary questions encourage the challenging of currently held conceptions of a problem situation and may support participants in conceptualising the problem in new but relevant ways. As such, elements that may be critical to the problem and the design of a successful intervention that have previously been neglected – "marginalised" elements – may be uncovered. Drawing on a wider range of perspectives – particularly those of marginalised individuals or groups – increases the probability of uncovering such marginalised elements in problems where the prevailing narrative is shaped by dominant stakeholders.

3.11. Conclusion

CSH has been applied by researchers across a range of problem domains. Most commonly, the approach is chosen because of coercion or asymmetric power structures inherent in the problematic situation. While it was not Ulrich's intention for CSH to be applied exclusively to address coercion, the framework provides a mechanism for doing so that surpasses soft OR methodologies. This is not only because CSH directly considers the problem through the lenses of control and legitimacy, but also because the practice of boundary critique aims to challenge and comprehensively understand different perspectives, irrespective of the dominance with which they are held. Several authors have discussed the benefits of this slower, deliberate mode of inquiry over a more action oriented SSM approach (Torun & Torlak, 2022; Venter & Goede, 2018). Moreover, we have attempted to clarify how the practice of boundary critique may lead to methodological emancipation, and distinguished this concept from the ideological emancipation of marginalised groups and individuals sought by many CSH users. While objectives of emancipation of the latter kind is not a requirement of CSH, in many studies they come hand in hand with aims of methodological emancipation, and CSH research frequently advocates for the voices of marginalised groups. CSH has faced criticism over its ability to adequately address coercion but action research in particular demonstrates the beneficial outcomes that the approach can deliver in such problem contexts. The underpinning ideas of CSH are complex, but it is at its core a versatile method for comprehensively understanding different perspectives on issues and why they are held. We hope that this review has helped to unpack key CSH terminology with reference to practical applications, so that more researchers might consider adding the approach to their methodological toolkit.

Chapter 4. Exploring Perspectives on Agroecological Transition in Scotland with Critical Systems Heuristics

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4.1. Overview

CSH is a framework that facilitates reflective practice in exploring and solving complex management problems. Several applications have demonstrated the utility of CSH as a framework for addressing problems concerning the environment and sustainability. As such, we apply CSH to explore perspectives on agroecological transition in Scotland. In interviews with 10 farmers, agricultural professionals, and researchers, we demonstrate the utility of boundary critique as a practice for unpacking the judgements that underpin perspectives on Scottish farming. Moreover, we derive a series of practical insights and recommendations to progress agroecological transition in Scotland, including: support for a greater diversity of farming systems; action across the entire food system to avoid "lock-ins"; improved tools to measure farming outcomes; and nuanced and precise conversations regarding the nature and purpose of agroecological farming. We hope that our accessible and transparent approach might encourage an uptake in CSH research among systems researchers and practitioners.

4.2. Introduction

The systems thinking tradition evolved in three distinct waves throughout the second half of the 20th century (Kish et al., 2021). The first conceptualisations of systems thinking were of "hard" systems. These are real – in that they exist independently of ourselves - goal seeking systems that can be controlled and optimised for a given purpose (Checkland, 2000). Examples include systems analysis and systems engineering (Jackson, 2009). The second wave to emerge was "soft" systems thinking – this tradition recognised that the social dimension inherent in complex management problems gives rise to multiple realities, and so a new set of tools was required to structure and solve such problems. Grounded in the interpretivist paradigm, these

tools can be used to capture and explore subjective "systems of thought" (Checkland, 1993, 2000). Finally, the third wave to evolve was critical systems theory. Most fundamentally, critical systems thinking sought to develop approaches that promote reflective practice within the systems tradition (W. Ulrich, 2003). Key concepts to emerge from the critical systems wave are the "System of Systems Methodologies", which proposes a framework selecting the most suitable systems methodologies for different types of problems (Jackson & Keys, 1984), and CSH, a framework to support reflective and emancipatory research and practice (W. Ulrich, 2003).

CSH is a systems framework that can be used to unfold different perspectives on complex management problems and make transparent the assumptions that underpin different worldviews (W. Ulrich & Reynolds, 2010). This is achieved by defining a set of boundary questions which explore the problem through four different lenses: motivation, control, knowledge, and legitimacy. As in the "soft" systems tradition, CSH assumes the existence of multiple, subjective realities (Checkland, 1993). However, CSH is distinct in outlining a process for critically reflecting on the reference systems that shape our realities, positing that a route to beneficial change is through understanding the judgements that give rise to different perspectives. Ulrich defined three categories of judgements that shape perspectives: 1) boundary judgements, 2) fact judgements, and 3) value judgements. Boundary judgements define what is and what is not relevant to the problem, fact judgements relate to what we know or expect about the nature of reality, and value judgements apply measures of worth – whether something is desirable or undesirable, right or wrong etc. (W. Ulrich & Reynolds, 2010). These types of judgements interact with one another, and ultimately shape our perspectives on any given situation.

CSH has been applied in a range of different problem contexts in recent years, including healthcare (Gadsby et al., 2022), education (Manduna et al., 2022; van der Linde & Goede, 2021), information systems (Mirhosseini et al., 2021), finance (Dehghan Nayeri et al., 2020), business intelligence systems (Venter, 2019; Venter & Goede, 2018), and performance assessment and evaluation (Gates, 2018; Mejía et al., 2019). Several authors have also applied CSH to explore management problems concerning the environment and sustainability. Lyons-White and co-authors (2022) explored a zero deforestation strategy in Gabon, outlining an approach that was guided by CSH throughout, from the conceptualisation of an initial reference system to presentation and communication of their findings. In an exploration of coastal

conservation in the Philippines, Klocker Larsen (2011) emphasised the requirement to adapt the CSH framework to the problem context so that boundary critique is tailored to existing stakeholder relationships. Cleland and Wyborn (2010) applied CSH in two ecohealth case studies that explored the interaction between environment and health. Their case study on national park management in Australia used the CSH framework not only to guide interviews, but also to problem-structure and analyse interview data. Further, their second case study which explored coral reef management in the Philippines integrated CSH for the purpose of addressing an issue influenced by inherent power asymmetry, and to facilitate reflection and awareness of the implications of conducting their research in participants in a deprived community. Finally, Simbolon (2017) reflected on an Indonesian city's decentralised water management system and used the CSH framework to derive a series of practical recommendations for change. These studies demonstrate the utility of CSH as a framework for more comprehensively understanding complex problems involving coupled human and nature systems.

This study considers how judgements of boundary, value, and fact shape perspectives on agricultural transition in Scotland. Agriculture has come under growing scrutiny in recent years, at least in part owing to increased recognition that addressing the climate and environmental crises necessitates food system change (Willett et al., 2019). Problem structuring methods are well suited to exploring issues involving agriculture: farms are coupled human and nature systems; the context of the climate and biodiversity crises as well as global food security issues means that farming objectives are increasingly complex; and farms are embedded within multi-actor food systems (T. Williams, 2008).

We focus specifically on agroecology as a vision for the future of Scottish agriculture. At a farm-level, agroecology aims to develop productive farming systems with reduced dependence on chemical inputs (Nicholls et al., 2016). More broadly, agroecology is a social movement that aspires to transformation of the industrial food system (Dumont et al., 2021; Wezel et al., 2009). Our research employs CSH to explore the perspectives of individuals with expertise in Scottish farming. In doing so, we aim to both clarify the role that agroecology can play in Scotland's agricultural transition, and uncover recommendations for beneficial farming and food system change. Further, we aim to demonstrate an accessible and transparent approach that might encourage an uptake in CSH applications among systems researchers and practitioners.

4.3. Methodology

Various methodological designs have been proposed in applying CSH. It is now regularly used as an analytical framework to retrospectively explore and critique understandings of qualitative data (Donaires, 2006; Gadsby et al., 2022; Levin et al., 2017; E. Tavella, 2016). One of the benefits of this approach is the ease with which it can be applied – interviews need not adhere to CSH's boundary questions, and the research output is not dependent on the effectiveness with which boundary critique is practiced during data collection. Other applications of CSH are more closely aligned with Ulrich's design, in that CSH features more extensively in the research design, guiding data collection from the outset (Cleland & Wyborn, 2010; Kish et al., 2021; Klocker Larsen, 2011; Venter & Goede, 2018). Our research follows more closely this second approach, adopting CSH as a framework for guiding inquiry and reflection (W. Ulrich & Reynolds, 2010), while also incorporating features of a more pragmatic orientation.

Interviews were conducted between April and June 2022 with 10 individuals working in or with Scotland's farming sector, and who had agroecological experience or knowledge. Participants included 4 males and 6 females – we believe achieving this balance of perspectives is imperative given the recognised need for greater gender equality in Scottish agriculture (Scottish Government, 2021d). Each interview took place remotely and lasted between 45 minutes and 1 hour. Participants were purposively selected, and included farmers that were integrating agroecological practices and principles into their farming systems, individuals working for agricultural organisations that were active in or exploring agroecology, and academics involved in agroecological research (Table 8). Different strategies were employed in recruiting participants. Firstly, several prominent researchers of agroecological farming in Scotland were contacted and invited to interview. Secondly, organisations that had published recent reports on agroecology were contacted and asked if they had eligible candidates available for interview. Thirdly, agroecological farmers in Scotland that the author was aware of through previous exploration of this network were invited to interview, with an aim of recruiting participants from different farming systems. Finally, at the end of each interview, participants were asked if they had recommendations for additional interview participants (Appendix 4). Interview participants were provided with an information sheet explaining the purpose of the research and a consent form in advance of the interview (Appendix 3).

The intention behind recruiting participants of different occupations – farmers, researchers, and other agricultural professionals – was to identify individuals from whom a breadth of ideas concerning agroecology's role in Scottish farming could be explored in detail. The research did not seek a consensus, rather it applied CSH to allow for and capture diversity in participants' perspectives. Agroecology is of growing interest in Scotland, but it is not widely implemented. Therefore, each participant was engaged or interested in an approach that deviated from Scottish farming norms. This idea of farming transition was of primary interest, and further motivated the selection of a research design based on CSH as the framework guides exploration of a system as it "is" and as it "ought to be". This was the framing provided to participants prior to interview – a desire to explore their views on farming in Scotland currently, and as they would like to see it.

The interviews were semi-structured and based on Ulrich's CSH framework. Rather than asking each of the 12 boundary questions in the "is" and "ought to be" mode, the interviews were designed more generally around the four "sources of influence" of the CSH framework. From a pilot interview, it was found that direct use of the boundary questions – and each in 2 modes resulting in a total of 24 questions – was an impractical interview format for participants. Instead, interviewees were asked more generally about farming as they saw it now, and farming as they believed it ought to be, and were encouraged to reflect on motivation, control, knowledge, and legitimacy. This format allowed for a more fluid interview in which participants were better able to express their views. Key boundary, value, and fact judgements made by participants during these interviews have been explored with explicit reference to Ulrich's 12 boundary questions.

Interviews were first transcribed from the audio files, which had been recorded using Zoom. Transcripts were then uploaded into NVivo 12 software, which was used to help with coding the data. For each transcript, sections of text that were relevant to motivation, control, knowledge, and legitimacy in both the "is" and "ought to be" modes for the system of interest were categorised. Each section of text was then translated into first order themes. These themes were stored in two tables – one for the "is" mode and one for the "ought to be" mode – under their corresponding categories (motivation, control, knowledge, or legitimacy) along with supporting quotes. Related first order themes were then grouped where suitable, resulting in a set of second order themes. These were categorised with increased specificity – rather than all falling under the source of influence (e.g. motivation) they were matched with the appropriate

boundary question for that category. This was an iterative process – it required reflection on whether the identified themes indeed matched their initial categorisation. Themes could be recategorised, merged, split into multiple themes, or removed if deemed to be irrelevant to the system of interest.

The second order themes for both the "is" and "ought to be" modes have been presented together in Table 9, to allow for comparison. The themes were used to form a narrative discussion that draws on key insights relating to participants' perspectives on farming in Scotland. Our discussion draws on these perspectives to make a series of practical recommendations for agroecological transition in Scotland, and also reflects on our methodological approach.

It is important to emphasise that our analysis and findings reflect our own reference systems. As the boundary judgements of the participants shape their perspectives on the issue of agroecological transition in Scotland, so too do our boundary judgements influence our interpretation of the interview data. The lead author, Hutcheson, grew up on a farm in Scotland and worked there part-time as a student. This background stimulated interest in the issues explored in this research but, importantly, also shaped his reference systems on agriculture. For this reason, we believe it was beneficial that authors Morton and Blair did not have agricultural backgrounds as it helped to identify underlying assumptions made by Hutcheson in interpreting findings, and with the communications of these findings for a wider audience.

Table 8. Interview participant details.

Participant	**Profession**	**Relevant experience**	**Sex**
A	Farmer, research co-ordinator at a farming-based organisation	Farmer self-identified as agroecological. Head of research at a Scotland-based farming organisation promoting agroecological livestock practices.	Female
B	Agricultural co-op development manager	Employee of a Scotland-based organisation specialising in agricultural	Male

Participant	Profession	Relevant experience	Sex
		co-operatives. The organisation has had recent involvement in a report outlining the role of agroecology in Scottish farming.	
C	Academic	Researching sustainable food systems with particular on crop-based systems. Works closely with farmers implementing agroecological practices.	Male
D	Academic	Researching agroecology with a focus on the diversification of farming systems for pest control and reduced dependence on external inputs.	Female
E	Farmer	Arable farmer exploring agroecological practices.	Male
F	Senior programmes manager at farming-based organisation	Employee of an agricultural organisation in Scotland promoting agroecology. Knowledge exchange facilitator working with farmers across Scotland.	Female
G	Academic	Ecologist researching hill and upland farming, and with particular interest in agroforestry.	Male

Participant	Profession	Relevant experience	Sex
H	Academic	Researching sustainable farming systems in Scotland with a particular focus on climate change mitigation strategies.	Female
J	Facilitator at farming-based organisation	Facilitator of regenerative farming group in Scotland, promoting knowledge exchange and agroecology.	Female
K	Crofter	Crofter[1] with a particular interest in agroecology and its implications for food and farming system change in Scotland.	Female

4.4. Findings

Table 9 presents the second order themes identified from the interview transcripts, with respect to how farming "is" and "ought to be" in Scotland from the perspectives of the interview participants. These themes have been categorised following CSH's 12 boundary questions.

[1] Crofts are agricultural landholdings in Scotland used for small-scale food production. Most crofts are tenanted but they may also be owned. The average size of a croft is 5 hectares (Scottish Government, 2021c).

Table 9. Farming in Scotland as it "is" and as it "ought to be".

Source of Influence	Boundary Question	Second Order Theme	
		Farming as it "is"	**Farming as it "ought to be"**
Motivation	Who is/ought to be the intended beneficiary of the system?	• Larger, productivity-oriented farming systems (A, B, C, D, G, J) • Large corporations (C, D, F, J)	• Farmers (A, B, D, F, J) • Consumers/communities (A, C, D, F, H, J, K) • The environment (A, B, C, D, E, F, G, H, J, K)
	What is/ought to be the purpose of the system?	• Productivity maximisation (A, C, D, G) • Provide an income for farmers (B, E, J)	• Provide an income for farmers (B, J, K) • Produce affordable, nutritious food for local communities (B, D, J) • Manage ecosystems and support nature (D, F, H, K)
	What are/ought to be the system's measures of success?	• Farm profitability (B, C, E, F, G, H, J) • Yield (A,C,D,E,H)	• Diversity (A, K) • Farm profitability (A, B, F, J) • Connectivity (F, J) • Productivity (E, G, H, K) • Emissions (J, H)
Control	Who is/ought to be in control of the	• Farmers (A, H, J) • Landlords (E)	• Consumers (H) • Buyers/retailers (A, H)

Source of Influence	Boundary Question	Second Order Theme	
		Farming as it "is"	**Farming as it "ought to be"**
	system's conditions of success?	• Retailers/buyers (A, H) • Policymakers (F, G, J)	• Farmers (A, F, H, J) • Co-operatives (B)
	What conditions of success are/ought to be under the control of farmers?	• Mindset (A, F, H, J) • Farming system resilience (A) • Flexibility in farming practices (E) • Livestock management (G)	• Considered and efficient land use (A, C, D, H, J) • Carbon footprints (E, H) • Livestock management (G, K) • Flexibility in farming practices (E)
	What conditions of success are/ ought to be outside the control of farmers?	• Administrative systems (A, G) • Climate (D, E) • Quality assurance (B) • Market for commodity crops (D, E, J) • Farm-level financial barriers (E, F, G, J) • Processing capacity (B) • Infrastructure (B, J, K)	• Policy framework that supports flexible and broadened role of farmer (A, J, K) • Financial support for small-scale food producers supplying local communities (J)
Knowledge	Who provides/ought to provide experience and expertise?	• Farmers (D, G, K) • Agronomists/advisors (D, G)	• Farmers (A, C, D, E, F, G, K) • Farming based organisations/research institutes (A, B, C, D, F, G)

Source of Influence	Boundary Question	Second Order Theme	
		Farming as it "is"	**Farming as it "ought to be"**
		• Farming based organisations/research institutes (A, B, F, G) • Books, online resources, and events (A, G)	• Books, online resources, and events (A, G)
	What information and skills do/ought they contribute?	• Experience with conventional farming practices and systems (D) • Science and research into both conventional and innovative farming practices and systems (A, D, G) • Experience with innovative practices (A, G)	• Integration of agroecological/regenerative practices at the farm level (D, J, G) • Effective grazing strategies (G, J) • How to communicate effectively (B, F) • Approaches to integration (across and within farms) (A, D) • Mechanisms for shared learning/knowledge exchange (D, F, J) • Strategies for re-channelling money paid into the farming sector (B,C,H) • Tools for measurement of outcomes (e.g. soil, biodiversity) (A,G,H,J) • Greater appreciation of complexity and nuance (E, K) • Enhancing farmers' confidence (A) • Adherence to nutrient management plans (H)

Source of Influence	Boundary Question	Second Order Theme	
		Farming as it "is"	**Farming as it "ought to be"**
			• Scaling up local vegetable production (J) • Support for farmer diversification (C)
	What are/ought to be assurances of successful implementation?	• Science and research (A, C, D, H) • Government policy (A, H) • Results based on previous experience (farmers, advisory services) (D, E)	• Science and research (A, C, D, H) • Government policy (E, H) • Results based on based on farmers' experiences (D, E)
Legitimacy	Who voices/ ought to voice the concerns of those adversely impacted?	• Farmers (particularly smaller, family businesses), the environment, the health of consumers, and food culture are adversely impacted in the current system. Their interests are currently not fully represented in agricultural policy (A, C, D, E, F, G, H, J, K)	• Farmers, agrochemical companies, supply chain intermediaries, private landowners, and the most vulnerable consumers have been identified as being at risk and requiring a voice (A, C, D, F, G, H, J, K).
	What opportunities are there/ought there be for the voices of the adversely impacted to be emancipated?	• Consultation between farmers, farming based organisations, researchers, and policymakers (E, K)	• Farmers ought to be able to turn to each other for support (D, F, J). • Farming based organisations can support and be proponents of transition (A, F) • Co-operatives can be a mechanism for change (B)

Source of Influence	Boundary Question	Second Order Theme	
		Farming as it "is"	**Farming as it "ought to be"**
	How are/ought to be opposing worldviews reconciled?	• Farmers currently viewed as the problem by some groups (J)	• Recognition that farmers are part of the solution rather than the source of the problem - consultation, discourse, and education among all food system actors. (F, J)

4.4.1. Who is/ought to be the intended beneficiary of the system?

Two actors emerged as the leading beneficiaries of farming as it is currently practiced in Scotland. The first is larger, corporate-style farms, and several participants (A, B, C, D, G, and I) expressed the view that farming is currently most viable for farms of this type. Participant B stated that farming in Scotland is currently at a crossroads. The sector has been showing increasing favour to larger, corporate-style farming businesses, while creating challenges for smaller farming business. He gave the specific example of livestock processing and described this as increasingly problematic for smaller farms.

> It's all too big, it's all too expensive, if we could make it smaller scale, more people could do it (Participant A).

The second beneficiary of farming as it is currently in Scotland – highlighted by participants C, D, and F – are large corporations, such as agribusiness and retailers. There was a perception that these powerful actors have come to dominate and dictate the direction of farming, from practices through to the produce we consume. Further, Participant F stated that the dominance of these corporations had increased over time, indicating that this was the current direction of travel for farming in Scotland.

> We've created a sort of globalised … capitalist system where all food is a commodity (Participant J).

In contrast to the increasingly fixed corporate mould that farming is currently oriented towards, participants described an ideal in which a diverse range of farm types and systems are supported in Scotland. The primary beneficiaries in this system would instead be farmers – of different types and scales – local and rural communities, and the environment.

> I think there will always still be a lot of those much bigger scale [farms] but, [we ought to be] allowing more development of the more diverse, small and medium-sized businesses (Participant F).

Participant C described a "bioregionalised" ideal, where, within reason, food was produced and consumed locally. Participant B outlined that the benefit of such a system is that money is channelled back into rural communities. Additionally, participant D explained that within

agroecology, there was an explicit focus on supporting the most vulnerable members of society, ensuring that the system both supports farmers and also provides healthy, affordable food.

> The whole ethos of agroecology is that you don't have negative adverse impacts on the most vulnerable in society (Participant D).

This provides an example of the interconnectedness of judgements of boundary, fact, and value that inform perspectives. Food inequality is relevant to participant D's perspective on agroecological transition (boundary judgement) because it is a significant societal challenge (fact judgement) that ought to be addressed though food system change (value judgement).

4.4.2. What is/ought to be the purpose of the system?

There was a sense among participants that farming in its current form does not adequately fulfil any of its core purposes, which were perceived to be: the provision of sufficient, healthy and affordable food; supporting farmers' livelihoods; and to manage and support ecosystems and nature. Instead, farming in Scotland was viewed as only adequately supporting the income of a subgroup of farms who prioritise productivity maximisation. Participant D stated that this form of agriculture had both socially and environmentally adverse impacts.

Several participants explained that a singular focus on productivity was no longer in keeping with our needs from a farming system. This was a model that had evolved during 20th century wartime and was now unsatisfactory in terms of its support for farmers, the environment, and the provision of healthy food.

> I think that what's wrong with the system we've got is history … We're still working to a post Second World War model of over producing and putting maximum input, maximum output, and it's just not relevant today (Participant D).

In contrast to the productivity maximising farming model described by participants, interviews conveyed that modern farming systems should serve broader purposes. Participants J and B were clear that farms were businesses that must provide farmers with an income. However, several participants (A, C, D, H and J) emphasised that farming was fundamentally about producing food, and that we ought to shift away from the production of feed, and towards the production of food directly for human consumption. Moreover, all participants recognised the responsibility and capacity of farms to support nature. For participant A, sustainable farming

meant achieving key outcomes relating to all of the economic, social, and environmental dimensions of her farming business.

> …when I talk about sustainability, I mean … against the triple bottom line. So people, planet, and profit (Participant A).

4.4.3. What is/ought to be the system's measures of success?

In alignment with the perceived purpose of farming as it is currently in Scotland, participants believed that success was determined by farm productivity and profitability. There were conflicting perspectives on the relative importance that these metrics played in ideal farming systems. This likely to an extent reflects the heterogeneity of farming types and systems, but is also indicative of a rise in alternative interpretations of agroecology (Miguel A Altieri et al., 2017; Levidow et al., 2014). Participant A stated the need to shift away from yield as the dominant metric, and that other metrics relating to environmental and social outcomes should be balanced.

> Yield is king has been … the cry for however many years (Participant A).

In contrast, Participant E, an arable farmer, stated that yield would remain the dominant metric for his business. He was actively exploring farming practices that had the potential to deliver superior environmental outcomes, but fundamentally the success of his business was determined by his yields.

Further, participant G, H and K discussed the need to maintain productivity. Participant G stated that flexibility in farming systems must be retained, as conventional systems may still be best suited to supporting some farmers, while Participant K described a general need among Scotland's crofiting communities to increase their productivity.

> …[crofters] are coming from something that has amazing habitat and amazing environment … but we need to be more productive (Participant K).

Participant H described the importance of maintaining productivity with reference to carbon emissions, which emerged as another measure by which successful systems ought to be judged. She emphasised that carbon emissions per unit of production may be higher in lower input, lower output systems. The satisfying of environmental objectives therefore appears to be a

challenging balancing act. Participants A and J expressed concerns that a sole focus on carbon emissions as a measure of environmental impact may detract from other important environmental measures.

Resilience was also raised as a potential indicator of successful farming systems. Participant A believed that agroecological systems were more resilient, and had the potential to be more profitable for farmers. Participant A also described a desire for more diversity in terms of what was produced on farms (and participant D outlined the potential pest control benefits of this approach), as well as a desire to see more integration of different farming enterprises. Farming in Scotland has become increasingly specialised over the last 50 years, and the synergies of agroecology can be better realised in mixed systems.

> I would like to see everything become more diverse and so more diverse cropping approaches [and] more diversity of integration (Participant A).

4.4.4. Who is/ought to be in control of the system's conditions of success?

Participants discussed several actors that they perceived to be in control of farming in its current form. Farmers were perceived to have some control over the design and implementation of farming systems. The way in which individuals farm is influenced by many variables, and is to an extent dependent on that individual's skills, resources, and values. However, participant F highlighted that anxiety about change was a barrier to agroecological transition, and therefore emphasised the importance of effective peer support networks among farmers to facilitate change.

> Some of [the barriers] might be social, as in … fear of change … So that that brings in the kind of peer support side (Participant F).

Crucially, many of the participants highlighted that transformation in Scottish farming required the input of actors across the entire food system. Participants raised the role of farmers, consumers, government, retailers, and agricultural organisations in facilitating change, and a transition to agroecology was perceived to be dependent on each assuming responsibility.

> You can look at it from both ends … do you need a policy push or do you need some kind of changing consumer behaviour? You probably need a bit of everything (Participant D).

The role of government in agricultural transition was perceived to be crucial, since Scottish agriculture is currently heavily dependent on government support. Currently, approximately 60% of farms in Scotland are only profitable because of government subsidies (Scottish Government, 2022a).

> …we still don't make a profit, anywhere near profit … We're completely reliant on subsidy, as [are] a large proportion of hill farms (Participant G).

Retailers were also acknowledged to have a role in influencing Scottish farming, largely due to their power in controlling food prices but also because of their specification of a particular "look" of produce that they are willing to buy from farmers. Participant A suggested that the financial interests of government and retailers are intertwined, and together they act as a barrier to transition to a transformative vision of agroecology. In contrast, Participant H described pressure from retailers to shift to more sustainable farming practices. However, she stated that there are transparency issues surrounding this pressure from retailers, and highlighted that the sustainability criteria that they define are often not standardised and shared.

> …how they are doing it, and what they are asking is quite hidden. So it's really in their circles, it's not very transparent (Participant H).

Several participants described an ideal system as being partially facilitated by consumer demand for sustainably grown food. Participants A and G, however, believed that there would need to be public acceptance that food ought to be more expensive. Education was also highlighted as playing an influential role in the success of agroecological farming. Participant J discussed the importance of consumer education for developing awareness of different ways of producing food and their implications. Education also covered training and knowledge sharing events between farmers and other industry professionals. Such events provide a platform for these individuals' ideas to gain traction more widely. A crucial aspect of facilitating knowledge exchange in farming is having the necessary systems and infrastructure in place.

> We need new tools and infrastructure for people to share their knowledge, and for people to have access to the training and support and advice that they need to try things out (Participant D).

Participant A described the importance of tenant and contract farmers effectively managing the relationships with their landlords. She believed that many farmers could take more initiative to find solutions to contractual barriers that can sometimes be a barrier to system change, for example, the integration of different farming enterprises may be contractually prohibited.

Furthermore, Participant B believed farming co-operatives were a potential mechanism for change in the sector. These are farmer-owned organisations that can provide support services and greater power in the marketplace. This was perceived as particularly important given the current dominance of retailers in the supply chain.

4.4.5. What conditions of success are/ought to be under the control of farmers?

Participants highlighted several variables that influenced the success of farming systems in Scotland and that could be controlled at least to some extent by farmers. Participants A, H, F, and I raised the issue of farmers' mindsets. There was a perception that many farmers held a fear of change, and a reluctance to shift away from the conventional farming practices with which they were familiar. However, participant H also recognised that such change places a cognitive burden on farmers which may present an additional challenge. Related to this, participant A believed that when farmers change their mindset and focus less on "externalities", they are able to develop more profitable farming systems.

> [Those farms] not necessarily worried about what's happening externally, are the farms that are more resilient. They're more fleet of foot, they're able to adapt, and they're able to be more profitable (Participant A).

Moreover, Participant E described different cultivation and drilling practices that he had integrated into his farming system, and believed that this flexibility was important and ought to be available to more farms. He had explored minimum tillage and direct tillage systems on his farm, with varying success. There was a clear economic benefit in integrating these practices into his business, in that they could result in significant savings on establishment costs through reductions in fuel and labour. Reduced tillage practices may also have an environmental benefit as they reduce soil erosion and potential leaching of nutrients (Lal, 2001). Participant E had the flexibility to choose between different drilling options in his business, and he perceived that this flexibility was key to running a successful farm. However,

he also acknowledged that his business was of sufficient size to be able to cover the costs of the multiple pieces of expensive machinery required to allow for flexible drilling practices, and that smaller farms may not have the financial resources to own multiple drills.

> Now I appreciate that is tricky for a guy who's only farming 500 acres, because he can't afford to have three different types of drill (Participant E).

This provides an example of barriers to sustainable farm management practices that exist for many farmers in Scotland. Participant B described the role that co-operatives can play in overcoming such financial barriers, by allowing farmers to split the costs of machinery between a group, giving each member access to equipment that they otherwise may not be able to afford individually.

> …by putting themselves into the machinery ring and spreading that cost over maybe another one or two farms … [they can] justify getting that machinery whilst everybody benefits (Participant B).

Participant G raised livestock grazing practices as another practice that farmers had some control over and that, when managed properly, could bring about environmental benefits. Despite this, in Scotland, much farmland is overgrazed, causing significant environmental harm.

> …over the centuries we've created a habitat that we graze with animals, most of which they can't actually eat (Participant G).

Participants E and H also raised the issue of on-farm carbon emissions, with participant E believing that this is something that farms will be judged on going forward, and participant H stating that so far little had been done to scale back agricultural emissions in the way that is required. She noted that frameworks exist to support farmers in doing this, such as nutrient management plans, but adherence to these plans can be an issue.

Finally, participants A, C, D, H, and J discussed the importance of careful consideration over what is grown in Scotland. Farmers may have a degree of control over this, for example, producing high quality beef for the local community is a central tenet of participant A's farming business. Nevertheless, the trend towards commodified food production has, for decades, also been shaped by factors outwith farmers' control.

4.4.6. What conditions of success are not/ought not to be in the control of farmers?

Participants C, D, E and J outlined that a favourable market for feed crops steered farmers to conventional systems. While Participant A had described the integration of agroecological principles as a route to improved farm profitability, this was not the experience of participant E.

> I love the idea [of an agroecological system] … you're reducing your carbon footprint … you're reducing compaction … [it's] less labour intensive so you've got less to do … It's a win, win, win, until it comes down to the actual money (Participant E).

Participants D and E highlighted that climate and variation between land types impact the viability of different farming systems. Participant D outlined that some practices, such as direct drilling, may not be suitable for some farmers because of their soil types. Participants E, F, G, and J also described the financial barriers to farming transitions, which may prevent diversification.

Participants were clear in that farmers should have the flexibility to transition their systems through the integration of sustainable practices, however, this required organisation elsewhere in the food system that is presently lacking. One example described by Participants B and J was processing capacity. Many farmers, particularly pig farmers in Scotland, were struggling with accessibility to abattoirs. This was described to be a particular challenge for smaller-scale farmers looking to run diverse, mixed systems. Government action is therefore required to ensure a suitable policy framework is in place to support necessary infrastructure changes if agroecological farming in Scotland is to be supported.

> Just to give Dumfries and Galloway as an example, we've got one abattoir … [it's] a three hour round trip … minimum, to get your livestock to the abattoir for five o'clock in the morning (Participant J).

Participants A and G also described issues with the administrative systems used for environmental government support schemes. Participant G believed that farmers may be put-off applying for these schemes because the application process is arduous. Participant A also viewed the inflexibility of administrative systems as a problem, since they fail to handle the integration of on-farm diversity, for example, recording fields that are in polycultures. She

believed that this rigid government support was a barrier to change, and that farmers instead ought to have greater flexibility in how they use these finances to support their systems, provided they can provide a justification of the environmental and/or social benefits.

4.4.7. Who provides/ought to provide experience and expertise?

Farmers' previous experience plays a leading role in shaping Scotland's current farming systems. Participant D outlined that problems could arise where farmers are tied to their previous practices, and unrecognising of the need to transition from business-as-usual agriculture. She highlighted that many farmers are over-reliant on external decision-making support, for example, in the form of agronomy services.

> [Some farmers] are very reliant on their agronomist to tell them what to do, or just reliant on what happened in the past (Participant D).

However, the experience and expertise of both farmers and other agricultural professionals, was perceived to be essential for a successful farming transition , given that agroecology is a knowledge intensive approach. Success requires farmers and professionals to share their experiences of alternative practices in order to both better understand which practices work well in different contexts and to gain greater adoption. Participants F and J highlighted the importance of engaging and working with farmers in their roles at farming-based organisations, and believe that this was a crucial learning mechanism. Different actors need to be working towards a common goal of transition, and effective channels ought to be open to facilitate knowledge exchange between these actors. There was a view that many individuals and organisations were working towards farming change in Scotland in the "right" way – through collaborations and placing farmers' experiences at the centre of transition.

Participants A and G also highlighted that there are many books, online resources, and events available to farmers as learning resources. However, the extent to which farmers use these resources will vary between individuals.

4.4.8. What information and skills are contributed by individuals with experience and expertise? What new knowledge is required?

Participant D described the wealth of knowledge and expertise about conventional farm management in Scotland. This has been supported by considerable technological advancements

since last century's Green Revolution, which has resulted in greatly improved farming productivity. However, there was a perceived need for research to reorientate its goals towards the development of alternative farming systems. Greater research is needed into the development of productive systems that build soil health and support biodiversity through the integration of suitable tillage techniques, lower dependence on fertilisers, and alternative pest control strategies that reduce the need for pesticides. Participant D described the specific example of intercropping – her research was exploring alternative crop management strategies that could reduce the pest burden by harnessing the symbiotic relationships between different crop species.

> Rotations themselves are devised to manage soil borne pathogens and pests, but things like intercropping can, in a similar way, reduce pest and pathogen burden (Participant D).

Participants G and J also highlighted the need for more research into effective grazing strategies. When managed correctly, livestock were viewed as an effective management tool that could support and enhance local biodiversity, while over-grazing could decimate local biodiversity.

Several participants described soft skills that are required for transition, but presently lacking in Scottish farming. Participants B and F highlighted the need for more effective communication strategies. Specifically, the ability of farming-based organisations to communicate research and evidence effectively with different groups. Different farmers were perceived to respond differently to different information. Participant A believed that farmers were often lacking the confidence to make changes to their systems, and that farming based organisations could play an important supporting role.

> I think you could have a whole project that is just comms, on what information there is already available … pull it all together and translate it into different formats for different audiences (Participant F).

Participant H stated that there is a need for better tools to measure more accurately farming outcomes. This is crucially linked to the design of effective agricultural policy, as without an accurate understanding of the impacts of different farming practices in terms of economic, environmental, and social outcomes, it is impossible to design policy that steers towards positive outcomes in these areas.

> The tools, monitoring tools which we have are not so good … [They are] not good enough to measure outcomes to provide outcome-based payments (Participant H).

4.4.9. What are/ought to be the assurances of successful implementation?

Interviews revealed that the current assurances of successful farming practice need not change, but the orientation of these systems requires realignment. Farming is and ought to be evaluated by science and research, government policy, and previous experience – be that of farmers or advisors. Nevertheless, change is required in each of these areas to reorientate goals towards farming systems that better support people and planet.

Participants described a need for effective policy to support a transition in the farming sector. Participant B believed agricultural policy ought to support the rechannelling of money generated in the farming sector, back into rural communities. Participant C believed there was a need for policy to better support farm diversification, and participant J highlighted the requirement for great support for smaller-scale vegetable production.

Moreover, participant A believed that there was already a large volume of credible research that could help farmers transition to agroecological systems, but we are currently slow in implementing the findings of this research in practice on farms.

> …we're just not good at sharing some of the research that frustratingly goes on in Scotland … the amount of researchers that are based in Scotland who are doing phenomenal stuff, and it takes like 20 years to get to the farmers. It's really frustrating (Participant A).

However, assurance of success also relates to the previously described need for accurate outcome-based measurement tools. Participant A highlighted that it is a challenge to measure and understand the potential longer-term financial benefits of implementing agroecological practices.

> …we don't have the ability to cost the savings … because the research is just so new and it changes, year on year and it's so complex (Participant A).

Participant B outlined the role farming co-operatives can play in ensuring farmers and rural communities are effectively supported in a farming transition. He described successful co-operative models in Denmark and the USA that Scottish farming could look towards and learn

from. He also detailed that Scottish agriculture has some of the highest quality assurance standards in the world, and that this ought to provide a useful platform in a sustainability transition.

4.4.10. Who voices/ought to voice the concerns of those adversely impacted?

Participants believed that many farmers were adversely impacted by Scottish agriculture in its current form. Participants B and C described how the corporatisation of food production in Scotland has been, and could continue to be, to the detriment of many farmers. Actors throughout the food system ought to recognise this, but it is the role of government to introduce a policy framework that supports more diverse farming approaches. Participant K believed that this would require a shift in the government's perspective on how agricultural land in Scotland can deliver value. She believed that crofts were currently viewed as incapable of making a productive contribution to Scotland's food system, and saw this perspective as self-fulfilling, as without legislative support from the government, crofting would be unable to realise its potential as a productive contributor.

> The national planning framework draft they put through recently … it basically said that all this area is good for is renewable energy and carbon sequestration … if that's the view of the government, then crofting is never going to thrive (Participant K).

Several other actors were highlighted as being potentially vulnerable in a transition to agroecology. Some farmers were perceived to still be at risk – Participant J expressed hope that farms that were more diverse would be more adaptable than larger, industrial-style farms. Participant G emphasised that any changes in agriculture that could bring about increased food prices, must be coupled with mechanisms to support society's most vulnerable. Participant C indicated that a transition to a bioregionalised food system may adversely impact retailers, and participants A and F highlighted that agrochemical and multinational food and drink companies may suffer. However, value judgements made by participants revealed little sympathy given that the power share of these actors in the food system was perceived to be out of balance.

> Big, corporate scale multinationals, I don't really care if they're impacted … I think that wouldn't be a bad thing really to support … actual people growing food for other people (Participant F).

4.4.11. What are/ought to be the opportunities for the voices of the adversely impacted to be emancipated?

While consultations between farmers and policymakers may play an important role in supporting a transition to sustainable farming systems in Scotland, participant E expressed frustration that despite the many consultations that had taken place, farmers were no clearer on the details of future agricultural policy. He believed that while it is important that farmers are given a platform to share their views and experiences in order to support effective and viable change, there was currently little evidence of tangible outcomes emerging from these discussions.

Participant A believed that new opportunities would arise for agricultural organisations, as farming attempts to reduce reliance on chemical inputs. She outlined that some companies are already capitalising on these opportunities, for example through the development of biological inputs.

> There are companies who are recognizing the change and are getting ahead of the curve and doing the work to produce something that might be of use to farmers (Participant A).

Strongly emphasised by participants was the role that peer support networks would play in ensuring farmers have the knowledge and skills to adapt their systems. Participant C perceived agroecology in practice to be ahead of the science in many ways, meaning that some of the best learning opportunities are from other farmers.

> You'd think that farmers would be following the researchers … but once a farmer gets aware that there's a future in something, oh my God, they're quick out the blocks, quicker than scientists (Participant C).

4.4.12. How are/ought to be opposing worldviews reconciled?

Participant J described the division that now exists within the environmental movement. She perceived that farmers were seen as the "enemy" by some groups and expressed frustration at this given the motivations of each group are generally aligned.

> …it's still very much an issue, this kind of ridiculous like sort of paradigm that we're in … this dichotomy vegans versus farmers (Participant J).

This ties into several ideas described under previous boundary questions. Strategies for effective communication between different groups that may have conflicting perspectives are necessary, but this requires clear articulation of the purpose and goals of a farming transition in order to facilitate nuanced and productive dialogue. Participant E described this need with respect to an enhanced understanding of the uniqueness of different farming contexts – practices that work for one farmer may not work for another and the assumption that they should creates unrealistic expectations.

> I just think sometimes people expect it to happen – you know, policymakers and stuff – expect it to happen overnight, because they might have read *Dirt to Soil*[2] or something like that (Participant E).

4.5. Discussion

4.5.1. Implications for Agroecological Transition in Scotland

In applying CSH to the issue of agroecological transition in Scotland, this study has identified a series of recommendations for change relating to: a necessary realignment of farming goals; need for co-ordination among all food system actors; knowledge sharing and the translation of agroecological research into practice; and the development of effective communication channels to facilitate open and nuanced discussion between individuals and groups with different views on the future of Scottish farming.

A recent survey of farmers in Scotland found that while 60% of respondents were practicing some aspect of agroecology, among many there was a lack of understanding regarding the

[2] Dirt to soil is a popular book written by North Dakota farmer Gabe Brown, in which he outlines his transition to a regenerative farming system.

wider environmental and social benefits to which agroecology aspires (Lozada, 2022). Our research supports this finding, in that farming in Scotland is perceived to be currently dominated by more intensive, productivity-oriented systems devoid of the environmental and social ethos inherent in a transformative agroecology (Wezel et al., 2009).

Participants were also clear in expressing the view that change in Scottish farming would require actors across the entire food system to assume responsibility. This "lock-in" effect has been previously identified in the literature, whereby individual actors are limited in the extent they can affect change without co-ordinated action elsewhere in the food system (Lawrence & Friel, 2019). An example described in this study was the requirement for increased consumer ability and receptiveness to higher food prices if farmers are to be able to produce more food following agroecological practices and principles.

Additionally, there is now unequivocal evidence that modern food production and consumption needs to change (Willett et al., 2019), and yet there is still a lack of consensus on the necessary direction of travel. For example, while there was a clear call from participants for greater diversity on Scottish farms, there was a divergence of views regarding the relative priority of yield in agroecological systems. Participant A believed the sector needed to move away from "yield is king", while others (Participants E, G, and H) emphasised the importance of focussing on yield, from the point of view of farm profitability, but also when considering farm carbon emissions (Cole, 2021). This supports the view that, as interest in agroecology grows, different interpretations of the approach have surfaced that may be more "conforming" (to conventional agriculture) or "transformational" (Levidow et al., 2014). For example, a UK report found agroecology to be an essential part of the sustainable intensification of agriculture (Lampkin et al., 2015). Many agroecologists would argue that the integration of these terms is evidence of agroecology's co-optation (Miguel A Altieri et al., 2017).

4.5.2. Boundary Critique

Our research has also evidenced an accessible implementation of CSH that retains an emphasis on boundary critique. When boundary critique is practiced in participant interviews, it allows for an unfolding of perspectives and accessing of knowledge that may otherwise remain unknown following a less reflective approach. In this way, we share Ulrich's view that CSH, or critical systems discourse (CSD) more broadly, is a framework to support reflection that ought to permeate throughout all systems thinking research and practice, as opposed to limiting

CSH specifically to a method most suitably applied to coercive problems (Kish et al., 2021; W. Ulrich, 2003). We instead see CSH as emancipatory in that it offers a structured approach for the transparent voicing of perspectives in complex management problems. In this way – by positioning reflection as a guiding principle - CSH can enhance systems thinking and problem structuring approaches. As such, CSH has facilitated the development of a deeper understanding of a topical and complex issue in Scottish agriculture, and has done so by providing a platform for individuals with perspectives that deviate from the conventional norms.

However, there are limitations to the CSH methodology that must be overcome. The academic framing of the boundary questions proved to be challenging for interview participants to follow as we found in a pilot interview. Moreover, the framing of each of the 12 boundary questions in both the "is" and "ought to be" modes means that a strict application of the CSH framework requires asking participants 24 questions while also allowing for prompting on specific boundary, value, and fact judgements that arise during the interview. We believe that this is impractical for most interviews. In adopting a more flexible interview protocol, while retaining a focus on boundary critique throughout, we have adopted a more accessible approach that retains reflection as the central tenet. The drawback of this approach is potentially capturing a less comprehensive picture of each individual's perspective on the situation of interest. Each participant may not be given the same opportunity to discuss every entity that is raised across all interviews. For example, we were not able to ask each participant about the role of retailers in Scottish farming – for several participants retailers were a relevant entity that they raised unprompted, but others did not mention their role in farming either is it "is" or "ought to be". However, as Ulrich outlines, the goal of CSH is not to seek consensus on a particular issue, but to provide a platform for discourse that feeds into the wider public sphere (W. Ulrich, 2003). We therefore do not perceive this to be a major methodological challenge.

4.5.3. Why Legitimacy?

Beyond a general emphasis on reflection throughout the research process, CSH offers specific benefits through its consideration of "legitimacy'. It is this dimension of CSH that has led to its association with coercive problem contexts (Algraini & McIntyre-Mills, 2018; Riswanda et al., 2017). Jackson and Keys (1984) excluded such problem contexts from their analysis in the development of SOSM, believing that external involvement in such situations is more likely to strengthen already dominant power structures than challenge them. We acknowledge this

critique but believe that in applying CSH in an exploratory capacity, this issue loses relevance. Rather than attempting to problem-solve within a single organisation, this study has explored a range of independent, anonymous perspectives, in order to surface knowledge about agroecological transition in Scotland and place this into the public sphere. Organisational politics has therefore not been a methodological barrier.

Nevertheless, the legitimacy-oriented boundary questions prompt participants to think about the situation of interest from alternative worldviews, with particular attention given to individuals or groups that may be adversely impacted. Interviews revealed that agroecological transition was in part about re-balancing the distribution of power in the food system. The value of "fairness" clearly fed into the change that participants thought ought to take place and, while there was certainly a lack of sympathy for perceived negative impacts on large agricultural suppliers and retailers, the practice of boundary critique prompted insights into alternative opportunities that such organisations are beginning to exploit. In the case of agricultural supplies, an example provided was a shift away from chemical to biological inputs; in the case of retailers, a growing consumer demand for sustainably produced food was highlighted as influential in their procurement. These examples illustrate the influence of boundary, fact, and value judgements in shaping participant perspectives. Perspectives do not simply describe what is and is not relevant to the problem, but they are shaped by understandings of truth and normative assumptions.

4.5.4. Limitations

A general limitation of our research is that our analysis and findings are presented through the lens of our own reference systems. Throughout data collection and analysis, we aimed to engage in a continual process of reflection to not only identify the judgements made by participants, but also to acknowledge that our own judgements shape our interpretation of their perspectives. Therefore, while we have aimed to be systematic and transparent in our interpretation of themes identified from the interview transcripts, it is important to acknowledge the influence of our own reference systems. Secondly, agroecological transition is a highly complex issue that is tied to social, economic, environmental, and political considerations across the entire food system. There are therefore many perspectives on this issue that might be considered relevant, and these could not all be captured in our research. Notable omissions for exploration in future research are the perspectives of policymakers,

agribusiness, and retailers, given that these were identified as important stakeholders by the study participants.

4.6. Conclusion

This research has uncovered insights into the role that agroecology can play in Scotland's agricultural transition. In particular, the findings have underlined the importance of the appreciation of nuance, effective communication, and co-ordinated action in accelerating change. Previous research had demonstrated the utility of CSH as a framework for uncovering practical recommendations for problems concerning the environment and sustainability (Cleland & Wyborn, 2010; Klocker Larsen, 2011; Lyons-White et al., 2022; Simbolon, 2017). We contribute to this body of research by proposing a transparent and accessible approach to conducting reflective interviews based on the CSH framework to explore a novel issue in Scottish agriculture. We believe CSH offers great promise as a method for exploring sustainable transitions, both as a stand-alone method and as a guiding framework for multi-method systems research. We hope that our research will encourage more researchers and practitioners to consider applying CSH as a reflective technique for identifying routes to improvement and barriers to change.

Chapter 5. Exploring Data Quality with Critical Systems Heuristics

5.1. Overview

CSH provides a versatile framework for exploring and realising beneficial change in complex management problems. However, application of the framework has been low compared with alternative soft systems methods. This chapter outlines an accessible and transparent approach to CSH and demonstrates its utility in an action research application. A workshop with an agricultural software company identifies opportunities for process improvements and formulates actionable steps to implement these changes. In doing so, this chapter aims to highlight the utility of CSH for action research in the context of agricultural transition.

5.2. Introduction

Ulrich's CSH was significant in shaping the critical systems thinking tradition and as such marked a key milestone in the development of the systems thinking literature (Midgley, 1997a; W. Ulrich, 2001). CSH aims at methodological emancipation by providing a platform from which different perspectives may be explored and given an opportunity to challenge dominant narratives. Accordingly, the framework has been commonly applied in problems where coercion and asymmetrical power relations play an influential role (Kish et al., 2021; Maru & Woodford, 2001; P. Tirivanhu et al., 2016).

CSH comprises of four distinct but related dimensions, each of which has three associated boundary questions. When considered collectively, these questions may be used to develop a comprehensive understanding of the problem of interest. The four dimensions are motivation, control, knowledge, and legitimacy. There are several core ideas to grapple with in understanding and applying CSH and which make it a versatile approach. CSH may be applied as a mechanism to provide a level playing field for different perspectives to be heard on complex issues. This is particularly relevant in situations where there is an evident asymmetrical power dynamic. Applications may aim to provide individuals or groups the opportunity to express their views on complex issues, who may not otherwise have the opportunity to do so (Ariyadasa & McIntyre-Mills, 2015; Riswanda et al., 2017). As a result of this, the methodological emancipation to which CSH aspires is frequently linked to goals of

emancipation for marginalised groups. CSH may also be applied with an emphasis on boundary critique, a mechanism for exploring conceptual models more deeply to surface the underpinning assumptions that shape them (Mejía et al., 2019; Mirhosseini et al., 2021). Finally, the framework has two modes of questioning – "is" and "ought to be". Reflecting both on the system as it is now and as it would be ideally enables users to identify elements that may be changed to bring about improvement. This is one reason that CSH appears to be useful in an action research context. While a specific focus on action is not inherent in the framework as it is in, for example, SSM, identifying the issues that prevent an ideal situation from materialising allows users to understand potential routes to beneficial change.

This study adopted an action research approach in applying the CSH framework to explore a problem of agricultural transition. The study investigates the data processes of a team within an agricultural software organisation based in the UK. The purpose of the workshop was to more fully understand the challenges faced by the team and to identify potential avenues for enhancing their data processes.

5.3. Methodology

This study was conducted with a small (40 – 50 employees) UK-based agricultural software company that processes and analyses farm data. They have an online platform that allows farmers to explore and visualise their data, with a view of supporting farm and field level decision making. Within the organisations are four core teams: engineering, product, commercial, and data. A workshop was run with five participants – four members of the data team and one member of the product team. Each participant was provided with a participant information sheet and consent form in advance of the workshop (Appendix 5). I have a professional relationship with the company, but the nature of that relationship cannot be disclosed without compromising confidentiality. My role as the facilitator was to structure the workshop and facilitate discussion. The workshop ran for four hours in total between 10 am and 3 pm with a one-hour break for lunch. It was run in person at the company office as a round-table discussion, with a PowerPoint deck outlining the overall structure of the workshop. Each participant documented their thoughts and insights on post-it notes and a flip chart throughout the session. All the written output was gathered at the end of the session, and I used this material to rapidly (within 48 hours) develop a document that summarised the key outputs of the process. This document was shared with the data team, and feedback encouraged.

The workshop was based on the CSH framework. The intention of its design was to ensure the intervention was accessible to the study participants and did not require prior knowledge of the CSH framework. CSH was applied as a structured approach to unfolding understanding of key issues. The workshop was developed around the four dimensions of critical systems heuristics, which was consciously simplified to allow a fluidity of discussion that would not be possible with strict adherence to the 12 CSH boundary questions considered in both the "is" and "ought to be" modes. Accordingly, the following framework, based on CSH's four "sources of influence" was used to guide the workshop:

1. Motivation – what is the data team aiming at and why?
2. Control – what can be influenced by who?
3. Knowledge – what are our present and desired levels of understanding?
4. Legitimacy – what might be the wider impacts of our actions and what ought we do about this?

These "sources of influence" and the accompanying questions are the foundation of the CSH process and open the door to exploring elements of the 12 CSH questions following a more accessible approach. Further, the principles that underpin CSH as a mode of inquiry were key to this research. The intention was to guide workshop participants through a process of critical reflection in order to develop a comprehensive understanding of the current and desired state of the data team's processes. In this way the approach intuitively also incorporates the "is" and "ought to be" modes of CSH, without having to purposefully structure the workshop and questioning around exploring the situation in either mode.

The workshop agenda was as follows:

1. Introduction

The workshop was introduced to the participants as a brainstorming session on data quality. This theme had been pre-arranged with the head of the data team, who wanted to explore this issue in detail. The introduction laid out two clear objectives: 1) identify where in the team's processes data quality is presenting the greatest issues, and 2) consider which actions can be taken to address these challenges and so contribute to the broader data team roadmap.

2. Icebreaker

Each participant was asked to describe one challenge and one recent improvement they have seen in the data team's processes. This was purposefully included in agreement with the data team lead and data process manager as it was viewed as a useful way of encouraging the team to not only brainstorm the obstacles facing the data team, but also action that has been taken to bring about improvement, in alignment with the workshop objectives.

3. Motivation

We then considered the data team's processes through the lens of the first dimension of Ulrich's CSH framework – motivation. A recap of the core objectives of the data team outlined at a recent company all-hands session were displayed, and the team was asked to discuss these. Participants were asked whether they would include any additional objectives, and which objectives they saw as highest priority.

4. Recently Addressed Challenges

Participants were then guided through a discussion on challenges that had recently been addressed by the team. Some of these issues had been addressed entirely, such as checking seed varieties against seed products, and checking for products missing compositions. Others were still in progress, including checking application areas against fields areas and harvest areas, addressing failed crops and split fields, application dates falling outside the harvest year, and cover crop ingestion. This stage of the workshop was centred on the "knowledge" dimension of the CSH framework. The purpose was to ensure both that there was a collective understanding of the solutions that had been developed to address recent challenges, and that the whole team was aware of ongoing work and the solutions that were being implemented for previously identified challenges. This was designed to be an exercise in gathering knowledge of the current situation, while also probing additional knowledge that would be required for developing solutions.

5. Home Saved Seed

Continuing with the exploration of knowledge, the next stage of the workshop explored in detail the issue of home saved seed (HSS). This was an issue that had been on the periphery of the team for several weeks but had not yet been collectively addressed. I provided a recap of

what HSS is and why farmers might use it. This was followed by a discussion on how the team might go about processing this data.

6. Data Ingestion (Additional Checks)

The platform currently makes several data quality checks on any newly ingested data. However, there are also checks that are not made by the platform and which must be manually made by the data team. The purpose of this stage of the workshop was to explore which checks the team are still making manually and whether there were any automated solutions that could be implemented in the short to medium term, prior to the release of the new version of the platform.

7. Platform Checks

The next stage of the workshop was a second deep dive on a novel issue relating to data quality checks. At the time of the workshop, data quality checks were conducted on every new farm that was ingested into the platform. However, there was not a systematic process for checking the quality of data that had previously been ingested into the platform, prior to platform checks. The purpose of this exercise was to discuss the development of a process that could systematically explore and clean this data.

8. Understanding our process

Having accumulated a collective knowledge base on several specific issues, the next stage of the workshop focused on an overview of the team's process. Each stage of the process was considered – from receiving data to conducting platform inductions with farmers. Participants discussed which stages of the process were presenting the greatest bottlenecks because of manual data processing.

9. Routes to improvement

This stage of the workshop focused on the "control" dimension of CSH. Having reflected on both specific issues and the data team process more generally, participants were asked to outline the highest priority stage of the process that required improvement. The specific challenges in these stages of the process were outlined, along with potential routes to improvement. Significant attention was paid to which groups or individuals were able to address the specified challenge i.e. where control lay. This may lie collectively with the data

team, with specific individuals in the team, or with other groups or individuals within the wider team.

10. Wider impacts

Drawing on the "legitimacy" dimension of the CSH framework, participants were encouraged to consider what the wider impacts of their activities and action points might be. Specifically, participants were asked how the derived list of actions and recommendations might impact customers and the wider organisation. Participants were asked to give particular consideration to any potentially adverse impacts.

11. Recap and Reflections

In the final stage of the workshop, participants were asked to reflect on the material that had been covered over the course of the day. They reflected on whether the delivered list of actions and recommendations fed into the initially outlined team objectives, and also on the timescale on which the desired improvements are achievable.

5.4. Findings

This section provides an overview of the workshop outcomes and considers the extent to which this implementation of CSH was an effective approach for structuring the session. I aim to highlight the benefits and the limitations of the approach taken so that they might inform the development of future CSH interventions. The summarised actions and recommendations derived from the workshop indicate the stage of the data team's process to which they relate, the challenge they aim to address, and the action itself (Table 10).

Table 10. Key actions to address identified challenges.

Stage	**Challenge**	**Action**
Pre-Data Ingestion	Integrate data cleaning scripts checks into data ingestion	Raise with product team
Data Ingestion	Application date check	Raise with product team
Pre-Data Ingestion	Identify variety/seed mismatches earlier	Modify data cleaning scripts
Pre-Data Ingestion	Identify failed crop/split fields	Modify data cleaning scripts
Pre-Data Ingestion	Compatibility of GM files with data cleaning scripts	Modify data cleaning scripts
Pre-Data Ingestion	Ingesting cover crops and grass	Explore existing data; check if we can filter crops; raise with product team
Data Ingestion	Managing errors in bulk	Ask for update from product team
Data Ingestion	Fill missing prices	Raise with product team
Data Ingestion	Data ingestion search	Raise with product team
Platform Checks	Across-platform checks	Develop process for min/max benchmarking
Pre-Data Ingestion	Frontier specific sales/contract issues	Designing automated solutions

Insights	Insight relevance	Collect customer feedback from commercial team; continued automation
Platform	Nutrient display	Raise with wider team
Pre-Data Ingestion	Straw	Product board

5.4.1. Motivation

Several key motivations for the data team's processes were raised during the workshop. The group agreed that the three data operations objectives defined in a recent all-hands session were representative of what the group were trying to achieve. These were:

1) Specify and draft automations and smarter checks to reduce manual interventions during the data processes while guaranteeing data quality
2) Develop efficient processes for data ingestion to improve data accuracy and ingestion time
3) Increase the range and complexity of analyses to add value to the data and the product.

When discussing these objectives, it emerged that 1) and 2) were very closely linked – greater automation would help improve accuracy and reduce processing time. Participants were asked whether they viewed these objectives as higher or lower priority than developing the team's analytical capabilities. Interestingly, while the roles of participants within the team were different – some individuals spent more time on processing and others spent more time on analytics – there was consensus that the objectives were of equal importance. Analytics was dependent on the volume and quality of data, and the value that customers derived from the platform was dependent on the quality of analysis.

Moreover, through discussion emerged another objective of the data team:

4) Defining the data standard for the industry.

One participant raised the point that the team were pioneers in farm data processing. No other organisations were collating such breadth of farm data – products used, yields, sales, and contracts – and collating this information so that it may be presented back to farmers in a meaningful way. As such, the organisation was defining the data standard for the industry by setting requirements for customers regarding the quality and volume of data necessary for processing. The group discussed that, while the objective of the organisation was to process data of any format from farmers, practice had shown that there existed a feedback loop in this process. Conversations with customers about data formats and quality had a positive influence on subsequent data submissions from these farmers. As such, it was felt that the organisation was defining farmers' levels of expectation and influencing behaviour when it came to farm data processing.

My role throughout the workshop was to stimulate discussion and encourage critical reflection. However, this workshop considered only motivation as a topic generally – without specific reference to the three boundary questions associated with motivation in the CSH framework (W. Ulrich & Reynolds, 2010):

1) Who ought to be/is the intended beneficiary of the system?
2) What ought to be/is the purpose of the system?
3) What ought to be/is the system's measure of success.

Notably, I found that by raising the topic of motivation generally and facilitating discussion among the group on this topic, each of the above boundary questions were addressed without the need for rigid questioning. For example, two key beneficiaries were outlined: 1) the data team (and the organisation more widely) and 2) farmers. The organisation would benefit from process improvements as it would enhance their service delivery and their processing capacity, and customers would benefit from improved data quality and insights into their farming operations. Purpose was addressed in the outline of the data team's objectives – these objectives were already core to the team's management. Objectives of the team had previously been defined by the data team lead and linked to the wider corporate objectives of the organisation. However, the workshop format afforded the opportunity to discuss these objectives as a group, which appeared to serve two benefits. Firstly, it was clear that there was consensus within the group that the previously defined objectives were representative of what the team was trying to achieve. Secondly, the discussion surfaced an additional objective – defining the data standard for the industry. This objective was particularly interesting, as it encourages consideration of the data team's processes through the perspectives of customers, as opposed to being entirely organisation centric. Insights of this kind are one of the core benefits of adopting a CSH-based approach. Finally, the key measure of success discussed by the group was reduced processing time. Again, this was an issue regularly visited by the team, who had conducted analytics on processing time and the variation in this for data of different quality.

It is clear that any organisation with a strategic plan would naturally be concerned with who they are trying to serve, what they are trying to achieve, and how they can monitor their progress. This application of the CSH framework was an intuitive and effective approach for answering these questions and suggests that rigid adherence to pre-defined boundary questions is at best unnecessary, and at worst may inhibit the kind of organic, fluid discussion that is so valuable in such workshop settings.

5.4.2. Control

The issue of control emerged as particularly important for the data team in considering the development of their processes. This is because, in the medium to long term, the organisation plans to release an updated version of the data ingestion engine, which will perform more automated checks and allow for more online – as opposed to offline – processing. However, the development of the new ingestion engine is primarily controlled by different teams within the organisation – engineering and product – and the timescale for release is uncertain. Therefore, the data team were required to make judgements on which temporary solutions for automation were worthy of their time and resources, and which issues were better raised with product and engineering for the development of the new ingestion engine. Participants agreed that some actions could be taken internally within the team, such as updating the data cleaning scripts for data processing. Other improvements, such as additional data ingestion checks, date checks, filling missing prices, were deemed more suitable as issues to be raised with the product team. Crucially, this exercise generated a well-defined list of actions that could be implemented by the data team over the coming weeks to improve their process.

The three boundary questions relating to control outlined in the CSH framework are:

4) Who is or ought to be in control of the system's conditions of success?
5) What conditions of success are or ought to be under the control of the system?
6) What conditions of success are or ought to be outside the control of the decision maker?

In designing an approach that focussed on surfacing the challenges faced by the team, while also aiming at actionable outcomes, I found that workshop participants reflected on what changes could be made, and who could make them. This was helped by the circumstance of one project participant, who had recently moved into a new role within the product team. This new role positioned him as the primary point of contact between the data team and product development. This was exceptionally useful when reflecting on actions that could be handled internally within the team, and those that could not, as it provided an additional "product" perspective that helped inform discussions on which issues might be more suitably addressed by the product team. Participants reflected on what could be managed internally, and what was better raised with the product team. As with the motivation stage of the workshop, these reflections took place without the need to rigidly adhere to the CSH boundary questions. I

believe that adopting this approach allowed for fluidity in discussion while reflecting on the key issues on which the control boundary questions are intended to facilitate consideration.

5.4.3. Knowledge

Knowledge was explored extensively throughout the workshop. There existed an important relationship between the team's knowledge (both current and desired) and the ability to influence or control the situation. Surfacing the team's collective understanding of specific issues, such as HSS data, allowed the team to consider the most suitable way of processing this data. After the team considered the issue of HSS, and drawing particularly on one participant's "product" perspective, it was agreed that the most effective approach would be an engineering solution. Therefore, collating knowledge within the team facilitated the identification of issues that could be addressed internally, and those that required collaboration with the wider team.

Collecting knowledge on key areas of the team's data processes also helped build a clear picture of the current and desired statuses of these processes. In initiating the workshop, the team lead was already focused on process improvements. In considering each issue, participants reflected on how they are currently addressed and how they might be addressed. For example, the team had a lengthy discussion on cover crops. Currently, cover crops are only ingested into the platform if they are included as a seed application prior to the drilling of another crop. However, much cover crop data is submitted by farmers as a distinct crop – this data is not currently ingested, but the team discussed why they felt it should be, drawing on customer feedback. Without purposefully structuring the conversation around the "is" and "ought to be" modes, these reflections took place organically. It appears natural to reflect on the situation of interest as it is, and as one would like it to be, in any action or change oriented intervention.

The boundary questions associated with the knowledge dimension of CSH are:

7) Who is or ought to be providing relevant knowledge and skills for the system?
8) What are or ought to be new knowledge and skills for the system?
9) What are or ought to be regarded as assurances of successful implementation?

Detailed conversations took place over the team's sources of knowledge. For some of the desired improvements, the knowledge required for execution existed within the team, such as for the redesign of the data cleaning scripts to include additional checks. Responsibility for these changes were assigned to one of the workshop participants. In other cases, the group

identified that they would be required to draw on external knowledge. For example, one of the issues discussed was the relevance of insights that the data team produced for their customers. In order to better understand this, the team realised that they needed to more closely liaise with the commercial team on insights, who not only had a clearer view on the general types of insights that customers would find useful, but also insights that might be tailored to specific customers. Therefore, discussions around the additional knowledge required within the team lead to consideration of from where this knowledge could be acquired. Regarding assurances of successful implementation, the primary metric that was used by the team was data processing time. Specifically, any changes that could reduce processing time while also maintaining data quality would be regarded as a successful intervention.

5.4.4. Legitimacy

The "legitimacy" dimension of CSH is perhaps the most distinguishing feature of the framework relative to alternative soft management science approaches. Despite this, it is regularly overlooked in CSH research. The legitimacy boundary questions are:

10) Who is or ought to be representing the interests of those negatively affected but not involved with the system?
11) What are or ought to be the opportunities for the interests of those negatively affected to have expression and freedom from the worldview of the system?
12) What space is or ought to be available for reconciling differing worldviews regarding the system among those involved and affected?

During this stage of the workshop, participants considered two key questions. Firstly, how might the listed actions and recommendations impact customers? Secondly, how might they impact the wider team? The workshop did not surface any expected adverse impacts for the customers. Each of the discussed changes to the team's processes were designed to enhance capacity to process more farm data, while maintaining data quality. However, consideration of impacts on the wider team prompted useful discussion. Most notably, it became clear that one of the participant's new roles within the product team created an important channel through which the data team could communicate their desired platform changes. This role was intended to ensure transparency throughout the wider team in terms of the processes and challenges faced by the team. Data processing is a key and limiting step of the company's wider goals and

so regular and clear communication regarding the data team's processes was viewed as essential.

5.4.5. Validation

Validation was achieved by considering which of the actions surfaced during the workshop had been acted on in the weeks following the workshop. The data team's data process manager participated in a follow up interview. Each of the listed actions were reviewed and their status was discussed. This interview revealed that, of the priority actions uncovered during the workshop, four had been successfully completed with resulting improvement in the team's data processing and management capabilities, while the rest of the actions remained in progress but incomplete. The completed actions were: identify variety/seed mismatches earlier; compatibility of GM files with data cleaning scripts; data ingestion search; and insight relevance.

During the validation interview, the participant was also asked for her perspective on the utility of the workshop. She was positive about the impact of the workshop and, notably, outlined that she was supportive of such interventions that could build common understanding. Specifically, she highlighted that finding ways to facilitate agreement between the data team on the key issues and challenges faced, gives them more power to emphasise these to the wider company and influence the allocation of resources to support the implementation of improvements.

5.5. Discussion

The described application of CSH follows an action research design. Action research is a collaborative approach in which researchers and participants work together to bring about improvement in the problematic situation of interest. Many CSH studies have adopted this approach and demonstrated positive outcomes (Ariyadasa & McIntyre-Mills, 2015; Dehghan, Khazaei, & Alinasab-Imani, 2020; Duboc et al., 2020; Goede & Taylor, 2019; Pinzon-Salcedo & Torres-Cuello, 2018; Taylor & Goede, 2016; Torun & Torlak, 2022; van der Linde & Goede, 2021; Venter & Goede, 2017, 2018). The CSH-based workshop reported in this chapter outlined a series of actions for the participating organisation to follow up with in order to bring about improvement to their data processes.

CSH is commonly applied in problem contexts that are influenced by coercion or asymmetrical power relations. The problem context of this chapter could not be considered typically coercive – there existed no conflicts that motivated the study, and each team within the organisation was aligned in striving for the wider company objectives. However, the multi-faceted nature of CSH makes it useful in problem contexts that are not overtly coercive, as has been demonstrated in several studies (Carr & Levidow, 2000; Mejía et al., 2019; Mirhosseini et al., 2021; Venter & Goede, 2017; Wallis et al., 2013). This study has provided further evidence to demonstrate that consideration of the "control" and "legitimacy" dimensions of CSH remain relevant in such problems, and allows for examination of the more nuanced influence of power in these situations.

An aim of this research was to outline an accessible approach to applying CSH. This application has intended to demonstrate that the framework may be flexibly applied. A key emphasis of this chapter is that, based on the findings of the CSH-based workshop, the four dimensions of CSH appear prompt questions that would be welcome in any strategic intervention. This insight has been previously noted by Ormerod (2004). Moreover, a useful function of CSH is "ideal mapping". That is, the framework can be used to outline how a situation might look in the best-case scenario, while reflecting on the current situation, in order to identify routes to improvement. This study found that elements of ideal mapping took place in the designed intervention. Thirdly, and most significantly, CSH as a mode of inquiry provides structure to a level of critical reflection that, in theory, surpasses alternative soft approaches. This is one of the key points made by Ulrich in his advocacy for the approach: the CSH framework should not be limited to only a subset of management problems in its application, rather its focus on

reflection and methodological emancipation ought to be inherent in all critical systems thinking approaches (W. Ulrich, 2003). The workshop intervention was perceived as allowing for free and open dialogue between different participants of different levels of seniority in the organisation. Of course, it could not be stated that a CSH approach guarantees this – the environment may have also been influenced by the existing organisation culture. However, awareness of the potential influence of power helps establish an intervention design that is more likely to achieve this outcome.

Addressing complex management problems through systems interventions is a balancing act. Exploring the situation of interest from multiple perspectives with high granularity is clearly only desirable to a point, for reasons of both relevance and practicality. Critical reflection in such interventions is crucial for developing a more comprehensive understanding of the problem, but researchers and practitioners must guide this process of inquiry with a focus on what is relevant and useful knowledge. Losing sight of this allows for the process to get lost in the complexity of social realities. However, approaches that are too prescriptive in labelling relevant and useful knowledge from the outset risk only summarising what is already known without uncovering novel insights. The challenge therefore to use the CSH framework as a guide while maintaining relevance to the problem of interest. Action research studies appear to facilitate this objective, given the research aims at beneficial and demonstrable change.

5.6. Conclusion

The reported CHS-based intervention facilitated process improvements for the data team within an agricultural technology organisation. In guiding participants through a workshop structured around motivation, control, knowledge, and legitimacy, participants were able to consider in detail their current processes, the specific challenges they faced, and derive a list of actions that contributed towards the overarching dual objectives of efficiency and data quality. A follow-up interview confirmed that several of the actions uncovered during the workshop had either been successfully implemented or that the team were in the process of implementation. CSH guided the session without structuring the workshop specifically around the 12 boundary questions. My own understanding of CSH as the workshop facilitator, coupled with an introductory explanation to participants that the workshop was centred on critical reflection, was a suitable level of methodological understanding to engage in the intervention. The practical, beneficial outcomes of this workshop are further evidence to support the translation of CSH principles into a format and language that is more accessible to research participants

(Cleland & Wyborn, 2010). I would therefore encourage CSH researchers and practitioners to consider employing the framework flexibly when using it in an action research context.

Chapter 6. Conclusion

6.1. Thesis Summary

This thesis has explored how agroecology is conceptualised and practiced in Scotland with an aim of understanding the role it might play in a sustainable farming future. A phenomenological inquiry based on interviews with farmers found that agroecology in Scotland is broadly aligned with a transformative vision that aspires to farm and food system redesign. It found that the foundational principles of the approach may be applied practically in a range of production systems including mixed, livestock, and arable farms, as well as smaller scale market gardens. Additionally, the experiential accounts provided by farmers indicated that smaller scale producers in Scotland appear to be the most authentic actualisations of agroecology. Each of these producers were not only integrating farm-level agroecological practices but were also engaged in alternative, local food networks that shortened the supply chain.

Agroecology in Scotland was explored further through the lens of CSH. A literature review of CSH found that this is a valuable framework that emphasises reflection in exploring different perspectives and why they are held. However, utilisation of the framework is low compared to alternative problem structuring methods. Applied to the issue of agroecological transition in Scotland, CSH uncovered insights necessary changes if agroecology was to become a more mainstream approach to farming. Interviews revealed the need for support for a diverse range of farm types and systems, co-ordinated action across the entire food system, and effective tools for measuring and evaluating farm-level outcomes. Further, interviews emphasised the importance of a clear articulation of the sector's goals for a farming transition. There was particular concern about the future viability of smaller family farms if the current trajectory in in Scottish agriculture is maintained.

The thesis also aimed to further explore and demonstrate the utility of CSH in the context of agricultural transition by applying the framework in an additional action research study (Chapter 5). This was a workshop-based application of CSH with a software company aiming to accelerate the transition to data-driven decision making in UK farming. This study found a CSH-based workshop to be an effective approach for uncovering key priorities for the organisation, and a follow-up interview revealed that several of these changes had been successfully implemented with resultant improvements in their data processes. Importantly,

this “light touch” CSH approach was easy to implement in an action research context and is accessible for systems researchers and practitioners.

In the remainder of this chapter, I consider how this research has helped inform on the role agroecology might play in Scottish farming going forward. I reflect on some of the key issues associated with agroecological farming uncovered during this research, and comment on their implications for wider adoption of the approach. Additionally, I suggest opportunities for future research into agroecology in Scotland. I then discuss CSH as a research method by reflecting on the applications outlined in Chapters 4 and 5. I consider whether the way in which CSH facilitates rich understanding of different perspectives is distinct from a soft systems approach, with specific reference to SSM. I also discuss the type of situations in which employing CSH may be of value, and draw on specific examples from Chapters 4 and 5 to demonstrate the utility of the approach for exploring problems relating to agricultural transition. The aim of these reflections is to consider the suitability of CSH in such problem contexts.

6.2. What role can agroecology play in Scotland’s agricultural transition?

6.2.1. Agroecology in Scottish Farming

Agroecology in Scotland was found to be a value driven approach to developing individualised, lower input farming systems. Each of the farmers interviewed in the phenomenological inquiry were aware of the environmental challenges that we currently face and believed that their farming approach could deliver positive change. However, they were also acutely aware that their farm management decision making had to make financial sense. Some farmers provided examples that illustrated a willingness to make some farm management decisions that were not economically optimal, but this was within the context of a profitable business. Additionally, there was a view that such decisions would support the future environmental and economic resilience of the farm.

The phenomenological inquiry revealed that the interviewed farmers, who were implementing aspects of agroecology in their farming systems, were broadly aligned with a transformative definition of the approach. This case can be made because most of the participants were engaged in alternative food networks. Short supply chains allow farmers to retain more of the value of their produce, as opposed to conventional supply chains in which much of the value

is captured by supply chain intermediaries such as processors and retailers. Alternative, direct supply chains align with the concept of food sovereignty, which is associated with an authentically agroecological food system and means that local communities have greater control over the food that is produced and consumed (CIDSE, 2018). Several farmers that participated in this research advocated for the social and environmental benefits of local food systems, but it was also clear that, particularly for smaller producers, direct sales were the only route to farm profitability. Even then, the financial viability of small-scale agroecological farming appeared to be questionable, given that several of the smaller-scale farmers interviewed also held second jobs that contributed to their household income.

Promisingly, in 2023 the Scottish Government recently announced that the Small Producers Pilot Fund would replace the Small Farms Grants Scheme (Scottish Government, 2023). This £180 000 fund is a positive step towards an agroecological food system, as the purpose of the new fund is to support smaller-scale producers and shorter, local supply chains through training opportunities and access to abattoirs. However, the potential impact of this fund must be kept in perspective, given the scale of Scotland's farming sector, which produces billions of pounds worth of output annually.

Therefore, it appears that farmers in Scotland are presently limited in the extent to which they can individually pursue a transition to an agroecological food system, in large part owing to market dynamics. Agroecologically produced fruit and vegetables are simply not valuable enough to allow for small-scale market gardens capable of providing a sufficient household income in the absence of diversification projects or alternative income streams. At the other end of the farming spectrum are larger-scale producers implementing agroecological practices such as minimum tillage and cover cropping into their arable systems. Such practices may lower input requirements for farmers and support more resilient farming systems, but they are limited in their capacity to contribute to an authentically agroecological food system if these farms primarily produce feed, and not food.

This is one reason that CSH appears to be a particularly valuable framework for understanding why different points of view are held, as it ensures each perspective is framed according to the goals and purpose of the system of interest. A view that was emphasised strongly by several participants during the CSH exploration outlined in Chapter 4 was that the primary goal of our farming systems ought to be to produce food. It can certainly be argued that Scotland's arable sector is not achieving this goal efficiently, with 44% of all cereals grown in 2019 being used

for malting, 35% for animal feed, and only 8% for milling (Scottish Government, 2021b). We must consider why this is the case and which levers can be pulled to reorientate the goals of our production systems, to prevent the inefficiencies of our food system from being a significant contributor to environmental decline. This appears to be the fundamental challenge of our food system – healthy, ecologically produced food is not valued highly enough and farmers lack clear economic incentives to produce food of this kind. Presently, agroecological farming in Scotland is reliant on the innovation and determination of a minority group.

Moreover, Chapter 4 uncovered a view that a transition to agroecology would require buy-in from actors across the food system and co-ordinated action. This is an important finding, as it is evidence against an increasingly popular narrative that farmers can improve the profitability of their businesses through the adoption of agroecological practices at the farm-level. While this may be the case in some farming contexts, greater nuance is required in communicating both the situations in which this statement might be true, and which agroecological principles and practices specifically deliver this. For example, arable farmers may improve their profitability by shifting to lower intensity tillage practices, which may lower fuel and labour costs. However, such systems may be more dependent on chemicals for weed control, and a shift towards reduced labour appears counter to an agroecological goal of supporting thriving rural communities. Further, market gardens are perhaps the most authentic implementations of agroecological production systems, but this research found evidence to suggest that the economic model for such farms in Scotland is poor. Therefore, an agroecological strategy implemented by farmers alone appears insufficient to establish viable, transformative agroecological systems.

Participants shared the view that change would instead require action across the entire food system. Specific actors and industries were singled out as being particularly inhibitory to an agroecological transition in their current form. For example, retailers were perceived to have too much power in the marketplace, forcing farmers to be price takers. Additionally, agrichemical suppliers were perceived to be supporting farming systems' dependence on chemicals with adverse environmental impacts. Participants also questioned the rationality behind such large quantities of Scotland's agricultural output being used as feed for animals or for the alcohol industry. While the focus of this research was predominantly at a farm-level, it emerged clearly that the kind of change to which agroecology aspires required a fundamental

re-evaluation of the goals of our food system as a starting point, and this cannot be achieved by farmers alone.

Despite this, there was clearly a view among participants interviewed across Chapters 2 and 4 that agroecology had the potential to deliver significant, beneficial change in Scotland both in terms of environmental outcomes, and farm profitability. However, more support is required to facilitate this change. I have already outlined the challenges faced by smaller-scale producers – additionally, larger scale producers aiming at agroecological transition are taking on risks when they decide to deviate from farming norms. Participants emphasised the need for knowledge sharing and enhanced communication channels to better share how farmers may practically begin changing their systems. For smaller-scale producers, likely more economically reliant on farm diversification, greater support – from government or elsewhere – is required to implement these changes. Also important is the development and integration of measurement tools to understand the impacts of changes in farming practices on key metrics, such as soil health, emissions, biodiversity indicators, and cost of production.

6.2.2. Future research on Agroecology in Scotland

One limitation of this research is that it has focussed primarily on agroecology at the farm level. Agroecology is an approach that ultimately aspires to change across the entire food system, and so perspectives across full agricultural supply chains are relevant. Future research therefore ought to explore the perspectives of these actors to better understand the implications of an agroecological transition. Ideally, this would be conducted in a collaborative setting that might allow different actors to identify and work towards shared goals. A suggested approach would be to identify specific supply chains in Scotland with an interest in agroecological transition, and to work with the involved stakeholders in an action research approach. A key question to explore would be whether co-ordinated action in such settings could better facilitate agroecological transition in these supply chains.

6.3. What is the utility of CSH for enhancing understanding in problems of agricultural transition?

6.3.1. Overview

CSH has been applied to understand in depth different, frequently conflicting perspectives across a range of problem contexts. It is a valuable method for achieving enhanced understanding in complex management problems and has been applied to deliver beneficial outcomes in action research contexts. CSH is widely used in situations where coercion or asymmetric power relations play a dominant role, and it is this aspect of the method that, for many, sets it aside from other problem structuring methods. However, despite its utility, CSH remains under-utilised compared to soft systems approaches such as SSM and cognitive mapping.

Authors have debated how CSH may be suitably applied since the framework was first proposed (Midgley, 1997a; Ormerod, 2004; W. Ulrich, 2003). Ulrich argues that the critical approach ought to be integrated into all systems approaches, while others view it as suitable for exploring coercive problems (W. Ulrich, 2003). Some authors have also questioned the capacity of CSH to meaningfully address coercive problems (Midgley, 1997a). Chapter 3 attempted to provide some clarity on key CSH terminologies with a view of better understanding why this disagreement exists and what it means for future CSH research and practice. Reflecting on these findings, I see it as important to articulate in greater detail why and how CSH might be a suitable methodological choice, with a particular focus on what distinguishes the approach from soft systems methods.

6.3.2. CSH vs Soft Systems Methods

Generally, we might say that CSH is applied to address complex management problems – but the same is true of soft systems approaches. In this section I aim to clearly outline the situations in which I believe CSH may be suitably applied (and preferably to soft systems approaches). There is no distinction between the conceptualisation of a "system" in a CSH application or a soft systems application (W. Ulrich & Reynolds, 2010). Both recognise systems as interpretations of reality that are informed by our experiences and worldviews, and different groups or individuals may therefore have different perspectives on the same issues. These conceptualisations contain different elements that relate to one another in some way, and

systems interventions aim to understand which elements are relevant to a given problem and the relationships between them. Soft systems theory has offered a series of practical methods for capturing and exploring these perspectives. However, CSH is distinct from soft systems methods in its implementation of the concept of criticality.

While the definition of a system is the same from both a soft and critical systems perspective, the key differences lie in the process we follow to formulate and understand these systems. Clearly, the CSH boundary questions are distinct from other approaches and so – while there may be overlap – the systems of thought constructed following CSH will be more suitable for investigations with a particular focus on control and power than systems constructed following alternative methods. An additional and more interesting influence is CSH's implementation of a process of criticality. Such a mechanism for facilitating criticality is absent in soft systems approaches. It is this criticality that is central to the deep understanding of different perspectives and why they are held to which CSH aspires. To demonstrate how the criticality inherent in CSH is distinct from soft systems approaches, I compare CSH and SSM.

While the specific objectives and methodological details of SSM applications vary between different studies and interventions, the guiding principles and methodological steps have been outlined by Checkland (Checkland, 1993, 2000; Checkland & Poulter, 2010). SSM focuses on first establishing a concise problem definition and then developing activity models that address the defined problem. It is an action-oriented approach that aims to bring about beneficial change in complex management problems. The approach key steps that SSM follows may be summarised as:

1. Exploring the problematic situation
2. Developing purposeful activity models
3. Debating the problem situation
4. Delivering improvement through action (Checkland & Poulter, 2010).

Like the critical systems perspective, the soft systems perspective acknowledges that different individuals may have different worldviews, different interpretations of the problem, and so different problem definitions and activity models. Checkland states that achieving improvement in the situation of interest requires the accommodation of different perspectives on the problem. Importantly, this does not necessarily involve achieving consensus between those involved, but it does assume that *enough* agreement can be reached to move forwards.

> An accommodation entails finding a version of the situation addressed which different people, with different worldviews, can nevertheless live with (Checkland & Poulter, 2010).

However, SSM does not detail a mechanism through which such agreement can be achieved. Understanding this is particularly important in problems with prevalent asymmetric power dynamics that may marginalise alternative perspectives. CSH attempts to address this issue by outlining a framework for gathering rich insights into the problem through which different perspectives can be clearly articulated with a view of achieving a clarity of understanding between participants that allow them to move forward. Therefore, CSH aims to provide a structure for facilitating and justifying progress through debate.

SSM acknowledges that different perspectives of the same problem may exist, and this requires a platform for discussion through which agreement about steps for improvement can be reached. This discussion takes place after satisfactory activity models of the problem have been developed. However, the methodology falls short in describing how debate over these activity models leads to shared understanding, agreement, and/or progress i.e. it is clear to see how SSM can facilitate recognition of the different perspectives of a problem and insight into how the problem might be addressed from these perspectives, but is not clear how stakeholders decide from these models, which are the most relevant, accurate, and impactful conceptualisations of the problem to bring about beneficial change. This is not to say that reaching such outcomes cannot happen through an SSM intervention – clearly it can, as demonstrated by the large body of action-oriented SSM research. However, the process through which this debate unfolds is unclear, specifically, the step between the conceptualisation of activity models and the recommendation of actions for improvement.

In contrast, CSH emphasises the mechanism through which we can rationalise how shared understanding between different individuals might be reached. The key difference is that criticality is built into the structure of the CSH framework. The boundary categories and questions are designed such that, when considered collectively, they provide a comprehensive view of the situation of interest. CSH aims for rich insights and, as a result, transparency of underpinning assumptions. To illustrate how this is achieved in practice, I draw on examples from my own CSH applications.

6.3.3. Example 1 – Yield is King?

In Chapter 4 I explored perspectives on agroecological transition in Scotland in an interview-based application of CSH. The objective of this research was to understand how each participant conceptualised agroecological transition in Scotland, and the use of CSH allowed nuanced differences in perspectives to be captured. An example of such was related to boundary question 3, *what is/ought to be the system's measure of success?* The interviews revealed that several participants held different perspectives on the relative importance of yield in our farming systems. One participant explicitly stated that farming needs to move away from yield as the dominant metric, whereas another viewed yield as the dominant metric (Figure 6). One of the benefits of CSH is that it allows us to unpack why these differences in opinion are held. This is possible because of the structure of the framework: as well as exploring measures of success, the motivation boundary category also aims to understand the purpose of the system, and who it aims to benefit. In understanding each, we can gain a clearer view of *why* particular metrics are deemed important for success. This approach is useful when exploring a concept that is not well understood, as it enables capturing of the areas of agreement and disagreement, which may help shape future conversations around that topic.

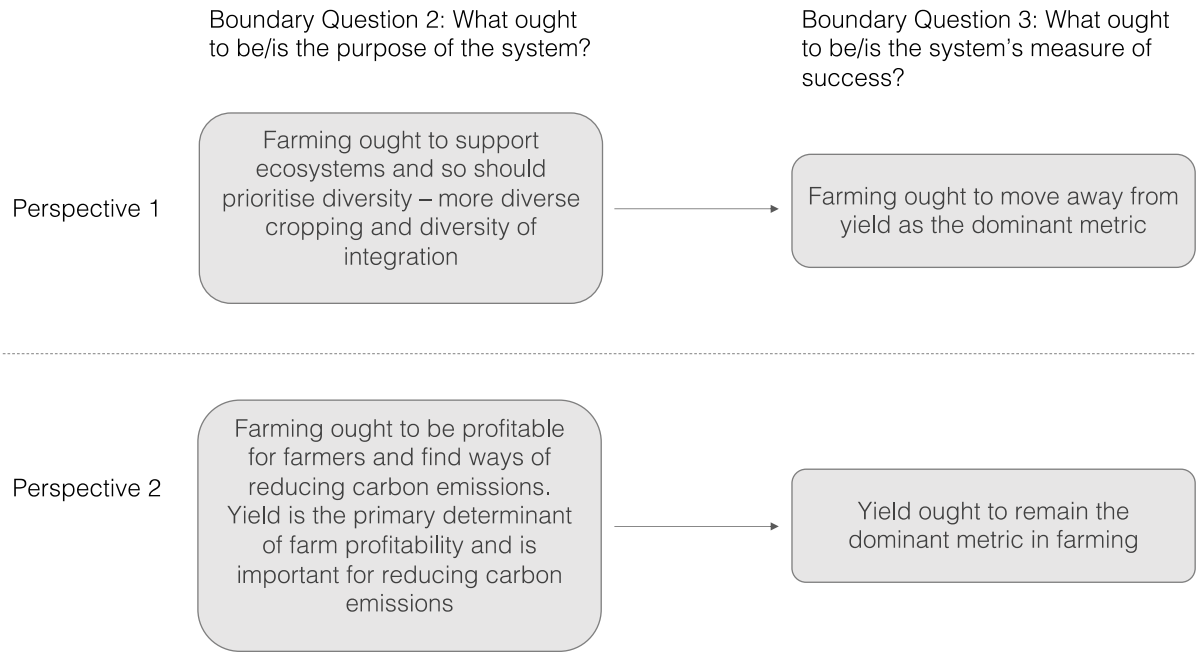

Figure 6. Illustration of the way in which the CSH framework helps unpack why different perspectives are held.

6.3.4. Example 2 – Bulk Editing

Chapter 5 explored data quality in a workshop-based CSH application with an agricultural software company. The data team had previously identified bulk editing capabilities in the online platform as the most pressing issue to solve in order to reduce data processing time. There was consensus among the group that this was the case. However, during the workshop one participant made the point that they felt bulk editing should be placed as a lower priority for the team. They were able to justify this through a discussion about control, and highlighted that the required changes for bulk editing had to be implemented by the engineering team and could not be put in place until a wider ingestion engine update had been implemented. As a result of this dependency, the group were able to rationalise that this fix was at least months down the line and their focus would be better spent tackling other issues. It is because CSH directly addresses the issue of control that the participant who raised the issue with bulk editing was able justify *why* this was a low priority activity and achieve agreement on this within the group. While such discussions may occur naturally without adherence to the CSH framework, CSH makes them more likely.

6.3.5. A Mechanism for Criticality

This critique is not to say that soft systems approaches cannot be applied critically. Stakeholders with different conceptualisations of a problem uncovered through an SSM intervention may also see that they have defined the purpose of their systems differently in their activity models. This is the second boundary question in the CSH framework, *what is/ought to be the purpose of the system?* In an application of CSH, participants with differently defined purposes would be encouraged to ask why these are different, and this would involve reflecting on who the intended beneficiaries of the system are (Boundary Question 1). Better understanding who the system is intended to serve can facilitate enhanced understanding of why the system purpose is perceived differently. This is core to CSH's criticality and is intended to provide shared clarity on why different perspectives are held, with the assumption that clarity of discourse makes more possible outcomes or activities that bring about beneficial change. However, applied with critical intention, SSM may facilitate the same level of understanding. After the purpose of the problem is concisely defined (following the PQR methodology (Checkland & Poulter, 2010)), participants debating different conceptual models with different purposes may then also ask, who do our systems intend to benefit? Checkland's CATWOE protocol encourages participants to list both the actors involved (A) and the problem owners

(O). Having considered and recorded these, participants may engage in a discussion over who the systems serve.

The key distinction is that, while soft methods may be employed critically, criticality is the fundamental principle on which CSH is based. Chapter 3 found that the CSH framework is largely applied to reflect and more richly understand different, frequently conflicting, perspectives on an issue. The specific application of the framework may vary, along with the problem context and nature of the perspectives that are being explored, but the core utility of CSH appears to lie in its ability to provide a level of clarity on different perspectives of a problem that enables us to better understand why these perspectives are held. CSH assumes that understanding *why* different perspectives are held is the key to the accommodation of these different perspectives, which is required for beneficial change.

6.3.6. Adapting the CSH Framework

A primary criticism that I have of the CSH framework is the low interpretability of the boundary questions. While the phrasing and terminology of these questions may be understandable for individuals familiar with soft and critical systems literature, most people (and therefore most participants) do not have such familiarity and will find the questions challenging to understand. This issue was highlighted by Larsen (2011) in a CSH application to coastal conservation in the Philippines. While CSH defines useful boundaries for exploration, the questions must be adapted to local contexts and audiences if they are to be practically useful. I found that this was the case in a pilot interview with a farmer in the exploration of agroecology (Chapter 4). Not only were the questions challenging to understand, but there were too many of them to cover in a single interview – each boundary question can be asked in the "is" and "ought to be" modes giving a total of 24 questions. Therefore, in both of my CSH applications, I designed a data collection protocol based on the CSH framework – as other authors have done (Cleland & Wyborn, 2010) – and did not adhere strictly to the boundary questions in their original form. Practically, this involved designing a semi-structured interview protocol and workshop format that facilitated discussion around each of the boundary categories: motivation, control, knowledge, and legitimacy. In both studies, when asked on these topics, participants raised issues or challenges with their current situations, which afforded the opportunity to probe further on how the situation would be under ideal circumstances.

It was clear after the pilot interview that the CSH framework would require adapting into a more suitable format if it was to be applied meaningfully to explore agroecology. As such, an interview protocol was designed that first asked participants to describe aspects of their ideal farming systems, before encouraging them to consider farming as it is now and the difference between these two modes (Appendix 4). This approach allows for a more fluid interview that gives participants more space to raise and describe the aspects of agroecology that are of interest to them. This initial deviation from the CSH framework also built my confidence in adapting the CSH framework to better suit participants and the problem context, and encouraged me to consider what changes might be suitable for a workshop-based approach.

Based on my experience conducting the CSH-based interviews for Chapter 4, I felt that applying CSH in a workshop setting would need to be even more "light touch". This was primarily because of the need to ground the approach in action research and drive change for the participating organisation. Workshop participants are more interested in beneficial, actionable outcomes than they are in understanding the benefits of any given methodological approach. It is therefore important to ground interventions in what works in practice (Ormerod, 2004). Drawing on my experience from the pilot interview, this necessitated moving away from a rigid adherence to the CSH boundary questions, towards an approach that aimed to facilitate discussion more flexibly around the CSH question categories (motivation, control, knowledge, and legitimacy).

6.3.7. Interviews vs Workshops

The most notable difference between the CSH applications outlined in Chapters 4 and 5 is that one study adopted an interview-based approach, while the other adopted a workshop-based approach. It is worth evaluating the strengths and limitations of each approach. One of the primary benefits of conducting one-on-one interviews is that it allows us to capture individual perspectives in detail. In contrast, workshop settings provide less opportunity to understand deeply each individual perspective. People have varying abilities to articulate their perspectives (Creswell & Creswell, 2013) and, in a workshop setting, individuals that are more articulate and confident may dominate the session. Accordingly, interview-based applications of CSH are well-suited to research objectives that aim to explore and understand an issue or concept more deeply, with particular interest in capturing nuanced differences between different perspectives. The application of CSH to explore perspectives on agroecological transition in Scotland

(Chapter 4) was an example of such a study. In other studies, workshops may be a more suitable methodological choice. In addition to being a data collection method, workshops also provide an opportunity for organisational learning, growth, and improvement (Shaw, 2006). Therefore, in an organisational setting where a group have shared interest in addressing a problem, workshops are a useful methodological choice for facilitating actionable insights that can bring about beneficial change. This was the case in the data quality workshop outlined in Chapter 5. A key output of the workshop was a list of actions which the organisation was able to take away and implement over the following months to improve their processes.

Users of CSH therefore ought to consider the implications of their problem type for the research or intervention design. Having outlined applications using both interviews and a workshop as a means of data collection, I recommend that users consider what they would like to be the key outcomes of the research. If the desired outcomes are action-oriented and it is possible to bring those involved together in workshops, this is likely the most suitable approach. However, if the purpose of applying CSH is primarily to understand the problem more deeply and capture nuanced differences between different perspectives, interviews will be a preferrable choice for capturing individual perspectives. In such situations, a premature focus on action without sufficient understanding of the problem may hinder the design of effective solutions for change (Venter & Goede, 2018). This insight may not be exclusive to CSH research, but true to problem structuring methods in general. Nevertheless, considering CSH specifically, I believe it is important to emphasise the utility of the framework for both exploratory and action-oriented studies.

It is also important to note that I have only explored two approaches to using CSH. Multi-method approaches that integrate interviews, workshops, or alternative data collection strategies may also be suitable, particularly for action-oriented studies. For example, preliminary interviews may help structure the problem, followed by workshops aimed at validating understanding and/or identifying actions for improvement.

6.3.8. Communication of Findings

A key consideration for CSH researchers is how they communicate the research findings. Commonly, authors choose to structure the research findings around the boundary questions (Gadsby et al., 2022; Kish et al., 2021; Venter & Goede, 2017). This is the approach adopted in Chapter 4, in the exploration of agroecological transitions in Scotland. The benefits of this

are that it provides a clear overview of the key, relevant elements that comprise the system of interest. If findings are presented in both the "is" and "ought to be" modes, it allows for capturing the key differences between them. It also clearly presents the differences and similarities between different participants. However, Chapter 5 did not present findings in this way. This is because of the action-oriented nature of this study. Instead, the findings were presented as a summary table of key actions and recommendations that were derived during the workshop. The benefit of this approach is that it makes clear the next steps that may be taken by the participants to affect change. It is also a convenient resource to re-visit in the future when reflecting on project progress.

While these are different frameworks for structuring findings, they have in common an accompanying narrative that follows the summary tables. In my view, the narrative is important for communicating CSH findings, especially for audiences unfamiliar with the problem context. A clear narrative that helps provide more context and explanation around why a particular boundary judgement has been made aids a level of understanding that likely is not present in a summary table alone.

These alternative approaches to communicating findings serve different purposes and, as with methodological choices, the most suitable approach depends on the research objectives. However, I would suggest that action research is likely less concerned with nuanced understanding of different problem boundaries than an exploratory study and is likely more interested in surfacing potential routes to beneficial change. I would encourage this line of thinking in helping to inform the communication of findings in CSH research.

6.3.9. Synergies Between CSH and Phenomenology

I ought to also reflect on the synergies of TPCA (trans positional cognition approach) and CSH. TPCA is a specific approach to phenomenological research that aims to integrate the positivist and interpretivist traditions through the process of bracketing. It aims to do this not by removing subjectivity, but by employing bracketing to make more transparent the assumptions and judgements that give rise to any given interpretation of events. It is grounded in Husserl's theoretical approach to phenomenological enquiry. Through bracketing, researchers are essentially attempting to engage in open-mindedness, so as to recognise how their biases and pre-conceived ideas might influence their interpretation of findings (Dörfler & Stierand, 2021). The approach is reflexive, and they key focus is on making transparent the way in which a

researcher's own lens impacts interpretation of participants' conceptual models of the situation of interest.

In contrast, the criticality of CSH is primarily about understanding and testing the underpinning assumptions of participants' conceptual models, to ensure clarity of discourse between different stakeholders. Ulrich's approach is heavily influenced by both Churchman and Habermas. The practice of boundary critique followed by CSH takes inspiration from Churchman's "process of unfolding" (Werner Ulrich, 1988) and Habermas's conceptualisation of the problem of rational discourse. However, Ulrich's view is that CSH provides a framework that is of greater practical utility as it is not inhibited by the ideals of the aforementioned scholars, namely, comprehensiveness or a clarity of discourse that delivers consensus (W. Ulrich, 2003). CSH instead seeks a level of understanding that enables the accommodation of different perspectives and outlines a mechanism to facilitate this.

A lack of emphasis on the kind of reflexivity initiated by TPCA – transparency of researcher interpretation – also has the potential to cloud or distort understanding of the viewpoints that are being explored in a CSH intervention. Given that undistorted communication is the goal of CSH (with the view that this is the best route to moving through complex problems), the influence of researcher biases and pre-conceptions is perhaps overlooked and as such is a limitation of the approach in its existing form. It may therefore be helpful for those applying the framework to formally integrate a step in which individuals that collected the data discuss their interpretation of the findings with colleagues further removed from the problem context. The purpose of this step would be to surface and question unconscious researcher bias that may influence the interpretation of findings.

6.3.10. Reflections on CSH for Explorations of Agricultural Transition

The second aim of this thesis was to discuss the utility of CSH for exploring problems of agricultural transition. I have attempted to demonstrate through a literature review (Chapter 3) and applications of the CSH framework outlined in Chapters 4 and 5 that the method is valuable and currently under-utilised. I have aimed to provide further detail on how and why the framework may be applied, and simplify the messaging around CSH by positioning it as a tool for providing greater clarity on perspectives of complex issues. Importantly, while soft systems interventions may also facilitate sufficient agreement on a problem for beneficial change to

take place, they do not outline how this is achieved. In contrast, CSH offers a mechanism through which individuals or groups may more clearly understand why different perspectives are held. It assumes that this level of understanding may facilitate the accommodating of different perspectives necessary to bring about improvement in complex problems. I believe an emphasis on this – that CSH aims at clarity of discourse – might widen use of the framework among systems researchers and practitioners.

Chapter 4 demonstrated that the framework may be applied for an in-depth exploration of different perspectives on agroecological transition, while Chapter 5 outlined a lighter touch application of CSH in which the framework was applied to guide employees of an agricultural technology company towards beneficial changes in their processes. However, an important consideration is whether the problem context of change in the farming sector is better suited than any other problem context to a critical systems approach. My view is that CSH has been a useful approach in the outlined studies because of their pluralist and complex nature. This is as true of farming change as it is a plethora of different problem contexts. Chapter 3 outlined applications to problems of education, business intelligence systems, community development, technology, and many others (Table 7).

Agricultural systems couple the natural and social worlds, and the interactions between them are highly complex. Therefore, while CSH is an effective approach for shaping and understanding such problem contexts, a sustainable transition in the farming sector will also require us to understand the measurable implications of any change in approach on the natural world. Qualitative research drawing on the experiences of individuals in the farming sector can yield valuable information in this context, but this must also be coupled with supportive quantitative data.

The absence of quantitative data may therefore be viewed as a limitation of this research. Having investigated how agroecology is conceptualised in Scotland, and how it is being put into practice at the farm level, future research ought to tie these insights to objective measurement of the environmental and economic implications of agroecology for Scottish farmer. This is a significant challenge that requires suitable farm management and environmental data from farms adopting agroecological approaches. Accessing the required volume and quantity of data of this kind is a challenge in the farming sector that the participant organisation of Chapter 5 is attempting to address. With this in mind, this thesis has highlighted the importance of tailoring agricultural innovations to different farming contexts and

recognising that sustainable agriculture cannot be a one-size-fits-all approach, has been noted in the sustainable agriculture literature. For this reason, I encourage future quantitative research not to overlook important qualitative insights that may help navigate the highly complex social world in search of successful and sustained implementation of agricultural innovation.

6.4. Limitations

This research has employed interview- and workshop-based applications of CSH, as well as phenomenological interviews to explore both how agroecology is conceptualised in Scotland and the utility of CSH for exploring problems of agricultural transition. A key challenge navigated throughout each component of this research has been researcher bias, which has the potential to distort reported findings from the experiences and realities of research participants. This issue was a motivation for selecting the TPCA approach outlined in Chapter 2. In bracketing, TPCA provides a mechanism through which users of the approach are deliberate in recognising the potential of their own lenses and worldviews influencing the study findings. This inescapable layer of researcher interpretation has the potential to take us further from the realities of research participants. For this reason, it was helpful for me to discuss the research findings with my supervisors with a view of surfacing any assumptions I may have made that could not be clearly linked to the collected data. I believe it is possible to adopt such a mindset for alternative approaches to qualitative research, but the benefit of TPCA is that it has formalised this step within the methodology in the form of bracketing. CSH does not formally outline a mechanism for addressing researcher bias in the same way as TPCA, and so CSH users may therefore wish to integrate such a step that aims to critically examine their own assumptions in interpreting the research findings.

Therefore, researcher bias clearly has the potential to negatively impact research findings. However, it is also important to recognise that the unique lenses through which we interpret the collected data also have the potential to enhance our findings. For example, I found that my upbringing on a farm helped facilitate more meaningful conversations with the farmers I spoke to throughout this research. Moreover, coming from a conventional farming background, I was also aware of the scepticism that is held by some towards agroecology and regenerative agriculture. Particularly in the public discourse, regenerative agriculture can be framed as a panacea for the environmental, economic, and social challenges facing our farming and food systems. I believe that this understanding helped in my critical evaluation of the views

expressed by research participants, enabling me to better distil those ideas that appeared to draw on practical experience from those that appear more ideologically based.

A further limitation of this research is that, in its exploration of the utility of CSH for addressing problems of agricultural transition, it has only reported two such applications of the framework. Agricultural transition is a broad context area containing many different challenges. There are clear differences between the problem contexts explored in this research – one exploratory investigation of agroecology in Scotland and one action research study that aimed to support a data driven agricultural software organisation. These are only two of many problems of change in agriculture that could be explored, and I would suggest that further applications of CSH in this area would help develop a more nuanced understanding of the situations in which CSH may work well, and those in which other methods may be more suitable.

Finally, this research has reported applications of an adapted CSH framework in both interview- and workshop-based approaches. Assumptions were made based on piloting regarding the suitable level of adaptation to the framework that would be required for meaningful applications of CSH. It would be interesting to test these assumptions through a research design that explored how different levels of adaptation impacted the utility of the intervention. This would deepen our understanding of the criteria that influence how and when adapting the framework makes is most suitable. It would also be interesting to understand how interviews and workshops may be integrated in a multi-step study. Section 6.3.7 reflected on the merits and shortcomings of interviews and workshops – a multi-step study could draw on the benefits of both approaches while mitigating their individual limitations. For example, in-depth interviews could be used for a preliminary exploration before bringing those same participants together in a workshop with a greater focus on action.

6.5. Concluding Comments

This thesis has aimed to enhance our understanding of agroecology in Scotland and the contributions it may make to improving the sustainability of the agriculture sector. Conceptualisations of agroecology at a farm-level are in alignment with a transformative vision of the approach, but action is required across agricultural supply chains to support widespread, viable transitions. I suggest that as a starting point, Scotland is clearer on what farming "ought to be". CSH has revealed that the current system is not achieving the goals of a sustainable,

agroecological food system: conventional practices are harming the environment, and smaller scale farming businesses appear to be becoming increasingly less viable financially.

CSH was applied in two studies following different approaches. The first application demonstrated that the framework is useful for exploring in detail perspectives on agroecology in Scotland. The second, lighter touch application of CSH used the framework to structure a workshop to identify data process improvements for an agricultural software organisation. This application appeared to be a suitable approach to using CSH in an accessible and participatory way, without requiring participants to have prior knowledge of systems approaches. Future research could adopt a similar participatory approach to an agricultural supply chain in Scotland interested in exploring agroecological transition. Of key interest would be to understand how different stakeholders can work together with this aim, and the extent to which CSH can facilitate.

I believe that CSH has not yet achieved the recognition it deserves for its contribution to the systems thinking literature. My own view is that this is at least in part because the unhelpfully complex terminology that accompanies the approach presents a barrier to understanding the framework. I recommend that those considering using CSH should ask: is improvement in the problem situation likely hindered by the existence of poorly understood or conflicting conceptualisations of the problem? If the answer to this question is yes, I would suggest that the research problem is well suited to CSH. As Ulrich intended, CSH is fundamentally concerned with achieving undistorted discourse (W. Ulrich, 2003). Further, practicability is another key issues that may contribution to low adoption of CSH. In some situations, the depth and transparency of understanding to which CSH aspires may far surpass that which is necessary to bring about improvement. Our research and intervention designs must remain grounded in what is useful in the real world (Ormerod, 2004). Therefore, in any given application, users ought to be clear on why a CSH-based approach is suitable as alternative methods may help them achieve their objectives more efficiently.

The emphasis of CSH on achieving clarity of discourse makes it valuable in complex problem contexts where alternative, conflicting perspectives exist. This thesis has aimed to demonstrate that CSH is a method that holds practical utility in the context of agricultural transition. We are in a period of environmental crisis and growing geopolitical instability, and our farming and food systems will surely continue to face significant challenges in the coming years. I believe that we would do well to draw on the principles embodied by Ulrich's CSH as we attempt to

navigate these challenges. Individuals, groups, and governments aiming to influence the future of agriculture ought to be prepared to accommodate different perspectives on the challenges and solutions for the sector, so that we might collectively move forward.

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Appendices

Appendix 1: Actualisations of agroecology in Scotland Participant information sheet and consent form

Participant Information Sheet

Name of department: Management Science
Title of the study: Agroecological Transitions: The Experiences of Farmers in Scotland
Introduction
This research is being conducted by Matthew Hutcheson, a doctoral researcher in the Department of Management Science at the University of Strathclyde. Matthew's research project is supervised by Professor Alec Morton and Shona Blair.
What is the purpose of this research?
This study aims to gather the experiences of farmers in Scotland engaged in agroecological transition. While much research has focused on the practices and principles of agroecology, less has considered the lived experiences of farmers that have embraced this approach.
Do you have to take part?
Participation in this research is voluntary. There is no obligation to take part and participants may withdraw without detriment.
What will you do in the project?
Participants in this research will be interviewed. Interviews may be conducted in person or remotely over Zoom. In either case, interviews are not expected to last longer than 1 hour. Interviews will commence in October 2021 and the investigation will run until April 2022.
Why have you been invited to take part?
You have been invited to take part as you have been identified as a farmer in Scotland engaged in agroecology.
What information is being collected in the project?
Interviews will be recorded and the transcripts will form the basis of analysis for this investigation. The data will be pseudo-anonymised, with transcripts saved under code names and a key to the code names stored in a separate file. Individuals will remain anonymous in all communication of outcomes.
The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.
Who will have access to the information?

Information will be stored and accessed only by the research team.

Where will the information be stored and how long will it be kept for?

The interview transcripts will be securely stored on OneDrive using the University cloud service. Transcripts will be kept until completion of the PhD (est. 2023), at which point they will be permanently deleted.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

All personal data will be processed in accordance with data protection legislation. Please read our Privacy Notice for Research Participants for more information about your rights under the legislation.

What happens next?

If you are happy to participate in the research, you should complete the below consent form. Please return this to Matthew Hutcheson (matthew.hutcheson@strath.ac.uk). At this point interview arrangements will be made.

If you do not wish to participate in this research, thank you for your attention.

We will seek publication of the findings of this investigation in an academic journal.

Researcher contact details:

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This research was granted ethical approval by the Department of Management Science Ethics Committee.

If you have any questions/concerns, during or after the research, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

Secretary to the University Ethics Committee
Research & Knowledge Exchange Services
University of Strathclyde
Graham Hills Building
50 George Street
Glasgow
G1 1QE
Telephone: 0141 548 3707
Email: ethics@strath.ac.uk

Consent Form

Name of department: Management Science

Title of the study: Agroecological Transitions: The Experiences of Farmers in Scotland

- I confirm that I have read and understood the Participant Information Sheet for the above project and the researcher has answered any queries to my satisfaction.
- I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my personal information will be used and what will happen to it (i.e. how it will be stored and for how long).
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences.
- I understand that I can request the withdrawal from the study of some personal information and that whenever possible researchers will comply with my request. This includes the following personal data:
    - audio recordings of interviews that identify me;
    - my personal information from transcripts.
- I understand that anonymised data (i.e. data that do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the research will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project.
- I consent to being audio and/or video recorded as part of the project.

(PRINT NAME)	
Signature of Participant:	Date:

Appendix 2: Actualisations of agroecology in Scotland Interview Protocol

Study 1 Interview Protocol

What Qualifies as a Farm-Level Agroecological Transition? Perspectives in Scotland.

Introduction

Thank you very much for agreeing to participate in this interview. The purpose of this investigation is to understand the experiences of agroecological farmers in Scotland. Over the course of this investigation I will be interviewing farmers to learn about their approaches and experiences. The interview should not take any longer than one hour. Do you have any questions before we begin?

Questions

No.	Theme	Question
1	Background	How did you get into farming?
2		How would you describe your approach to farming?
3	AET activities	What are the activities that you associate most with your approach to farming?
4		How did you acquire your farming skills and knowledge?
5		What do you think distinguishes your approach to farming from

		more conventional farming systems?
6	Objectives	What are you hoping to achieve with your farming system? What are your objectives?
7	Barriers	What are the barriers you encounter in farming?

Closing Remarks

Thank you very much for your time today. As covered in the participant information sheet and the consent form, the interview transcripts and communication of results is anonymised, and so you will not be identified by name. Do you have any questions for me?

Once this investigation has been completed, I will share with you an abstract of the final study.

Finally, I wondered if you know of any other agroecological farmers in Scotland who might be willing interview candidates?

Appendix 3: Exploring perspective on agroecological transition in Scotland with critical systems heuristics participant information sheet and consent form

Participant Information Sheet

Name of department: Management Science
Title of the study: A critical systems exploration of agricultural transitions in Scotland

Introduction

This research is being conducted by Matthew Hutcheson, a doctoral researcher in the Department of Management Science at the University of Strathclyde. Matthew's research project is supervised by Professor Alec Morton and Shona Blair.

What is the purpose of this research?

This investigation aims to explore perspectives on farming in Scotland through the lens of critical systems heuristics. In understanding the reference systems of where farming 'is' and 'ought to be', this study aims for insights into the opportunities and challenges for agricultural transition.

Do you have to take part?

Participation in this research is voluntary. There is no obligation to take part and participants may withdraw without detriment.

What will you do in the project?

Participants in this research will be interviewed. Interviews may be conducted in person or remotely over Zoom. In either case, interviews are not expected to last longer than 45 minutes. Interviews will commence in April 2022 and the investigation will run until October 2022.

Why have you been invited to take part?

You have been invited to take part as you have been identified as an individual with expertise in Scottish farming.

What information is being collected in the project?

Interviews will be recorded and the transcripts will form the basis of analysis for this investigation. The data will be pseudo-anonymised, with transcripts saved under code names and a key to the code names stored in a separate file. Individuals will remain anonymous in all communication of outcomes.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

Who will have access to the information?

Information will be stored and accessed only by the research team.

Where will the information be stored and how long will it be kept for?

The interview transcripts will be securely stored on OneDrive using the University cloud service. Transcripts will be kept until completion of the PhD (est. 2023), at which point they will be permanently deleted.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

All personal data will be processed in accordance with data protection legislation. Please read our Privacy Notice for Research Participants for more information about your rights under the legislation.

What happens next?

If you are happy to participate in the research, you should complete the below consent form. Please return this to Matthew Hutcheson (matthew.hutcheson@strath.ac.uk). At this point interview arrangements will be made.

If you do not wish to participate in this research, thank you for your attention.

We will seek publication of the findings of this investigation in an academic journal.

Researcher contact details:

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This research was granted ethical approval by the Department of Management Science Ethics Committee.

If you have any questions/concerns, during or after the research, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

Secretary to the University Ethics Committee
Research & Knowledge Exchange Services
University of Strathclyde
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50 George Street
Glasgow
G1 1QE

Telephone: 0141 548 3707
Email: ethics@strath.ac.uk

Consent Form

Name of department: Management Science
Title of the study: A critical systems exploration of agricultural transitions in Scotland

- I confirm that I have read and understood the Participant Information Sheet for the above project and the researcher has answered any queries to my satisfaction.
- I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my personal information will be used and what will happen to it (i.e. how it will be stored and for how long).
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences.
- I understand that I can request the withdrawal from the study of some personal information and that whenever possible researchers will comply with my request. This includes the following personal data:
    - audio recordings of interviews that identify me;
    - my personal information from transcripts.
- I understand that anonymised data (i.e. data that do not identify me personally) cannot be withdrawn once they have been included in the study.

- I understand that any information recorded in the research will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project.
- I consent to being audio and/or video recorded as part of the project.

(PRINT NAME)	
Signature of Participant:	Date:

Appendix 4: Exploring perspectives on agroecological transition in Scotland with critical systems heuristics interview protocol

Study 2 Interview Protocol

A critical systems exploration of agricultural transitions in Scotland

Introduction

Thank you very much for agreeing to participate in this interview. The purpose of this investigation is to explore perspectives on farming in Scotland through the lens of CSH This interview is structured on the CSH framework, which includes 12 questions aimed at exploring your understanding of farming as it 'is' and 'ought to be'. If you are a farmer, please consider your own farm when answering the questions. If you are not a farmer, please draw on your knowledge of farming systems in Scotland.

Participant Information Grid

Details	
Name	
Age	
Profession	
Organisation	

Questions

Sources of Influence	*Boundary Judgements Informing a System of Interest (S)*	
Sources of Motivation	Beneficiary	1. Who is/ought to be the intended beneficiary of the farming system?

	Purpose	2. What is/ought to be the purpose of the farming system?
	Measure of Improvement	3. What is/ought to be the farming system's measure of success?
Sources of Control	Decision Maker	4. Who or what controls/ought to control the conditions of success of the farming system?
	Resources	5. What conditions of success are/ought to be controlled?
	Decision Environment	6. What conditions of success are/ought to be outside of the farmer's control?
Sources of Knowledge	Expert	7. Where do/should farmers obtain the relevant knowledge and skills for their farming system?
	Expertise	8. What are/ought to be relevant knowledge and skills for the farming system?
	Guarantor	9. What assurances give/ought to give confidence the in knowledge/skills?
Sources of Legitimacy	Witness	10. Might anyone be negatively impacted the

		farming system? Who represents/ought to represent their interests?
	Emancipation	11. What are/ought to be the opportunities for individuals negatively impacted by the farming system to express their situation?
	Worldview	12. How are/might differing worldviews regarding the farming system be reconciled among those involved and affected?

Adapted interview protocol:

1. *Can you describe to me your ideal farming system in Scotland?*
    a. *What is the purpose or purposes of this farm?*
    b. *What determines the success of this farming system?*
    c. *What knowledge and skills are required for this farming system?*
        i. *Where can these be acquired?*
    d. *Might there be anyone negatively impacted by this farming system?*

2. *Considering farming as it is today in Scotland, what changes are required to realise your described ideal system?*

Closing Remarks

Thank you very much for your time today. As covered in the participant information sheet and the consent form, the interview transcripts and communication of results is anonymised, and so you will not be identified by name. Do you have any questions for me?

Finally, I wondered if you know of any other individuals working in Scottish agriculture who might be willing interview candidates?

Appendix 5: Exploring data quality with critical systems heuristics participant information sheet and consent form

Participant Information Sheet

Name of department: Management Science
Title of the study: Exploring data quality through critical systems heuristics

Introduction

This research is being conducted by Matthew Hutcheson, a doctoral researcher in the Department of Management Science at the University of Strathclyde. Matthew's research project is supervised by Professor Alec Morton and Shona Blair.

What is the purpose of this research?

This study aims to understand the impact of data quality on [redacted] data operations. The workshop will explore challenges and improvements relating to data quality.

Do you have to take part?

Participation in this research is voluntary. There is no obligation to take part and participants may withdraw without detriment.

What will you do in the project?

The study will involve a single workshop with [redacted] data team. This will be conducted in person at [redacted] office in [redacted]. The workshop is not expected to last longer than 3 hours and will take place in May 2023.

Why have you been invited to take part?

You have been invited to take part as a member of [redacted] data team.

What information is being collected in the project?

Workshop outputs will be made available to the data team. Participant information collected for the study will be pseudo-anonymised and saved on Strathclyde's OneDrive. Any workshop outputs used for the PhD will be anonymised, and the thesis will be embargoed so that the outputs of this study are not available to the public.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

Who will have access to the information?

Information will be stored and accessed only by Matthew.

Where will the information be stored and how long will it be kept for?

The workshop outputs may be kept by [redacted] indefinitely. They will also be stored on Strathclyde's OneDrive using the University cloud service. These will be accessible only by Matthew and will be kept until completion of the PhD (est. late 2023), at which point they will be permanently deleted.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

All personal data will be processed in accordance with data protection legislation. Please read our Privacy Notice for Research Participants for more information about your rights under the legislation.

What happens next?

If you are happy to participate in the research, you should complete the below consent form. Please return this to Matthew Hutcheson (matthew.hutcheson@strath.ac.uk).

If you do not wish to participate in this research, thank you for your attention.

Researcher contact details:

Matthew Hutcheson
University of Strathclyde
Strathclyde Business School
199 Cathedral Street Glasgow
G4 0QU

Email: matthew.hutcheson@strath.ac.uk

Chief Investigator details:

Professor Alec Morton
University of Strathclyde
Strathclyde Business School
199 Cathedral Street Glasgow
G4 0QU

Email: alec.morton@strath.ac.uk

This research was granted ethical approval by the Department of Management Science Ethics Committee.

If you have any questions/concerns, during or after the research, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

Secretary to the University Ethics Committee
Research & Knowledge Exchange Services
University of Strathclyde
Graham Hills Building
50 George Street
Glasgow
G1 1QE

Telephone: 0141 548 3707
Email: ethics@strath.ac.uk

Consent Form

Name of department: Management Science

Title of the study: Exploring data quality through critical systems heuristics

- I confirm that I have read and understood the Participant Information Sheet for the above project and the researcher has answered any queries to my satisfaction.
- I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my personal information will be used and what will happen to it (i.e. how it will be stored and for how long).
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences.
- I understand that I can request the withdrawal from the study of some personal information and that whenever possible researchers will comply with my request. This includes the following personal data:
    - audio recordings of interviews that identify me;
    - my personal information from transcripts.
- I understand that anonymised data (i.e. data that do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the research will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project.
- I consent to being audio and/or video recorded as part of the project.

(PRINT NAME)	
Signature of Participant:	Date: