RESEARCH

Check for
updates

Exploring Perspectives on Agroecological Transition in Scotland with Critical Systems Heuristics

Matthew Hutcheson[1] · Alec Morton[1] · Shona Blair[1]

Abstract

Critical systems heuristics (CSH) is a framework that facilitates reflective practice in exploring and solving complex management problems. Several applications have demonstrated the utility of CSH 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 the uptake of CSH research among systems researchers and practitioners.

Keywords Critical systems heuristics · CSH · Boundary critique · Agroecology · Sustainable agriculture

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, requiring a new

✉ Matthew Hutcheson
matthew.hutcheson@strath.ac.uk

1 Department of Management Science, Strathclyde Business School, University of Strathclyde, Glasgow, UK

set of tools 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 (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 and Keys 1984), and critical systems heuristics (CSH), a framework to support reflective and emancipatory research and practice (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 (Ulrich and 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. (Ulrich and 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 and Goede 2021), information systems (Mirhosseini et al. 2021), finance (Dehghan Nayeri et al. 2020), business intelligence systems (Venter 2019; Venter and 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 paper 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 (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 the uptake of CSH applications among systems researchers and practitioners.

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; 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 and Wyborn 2010; Kish et al. 2021; Klocker Larsen 2011; Venter and Goede 2018). Our research follows more closely this second approach, adopting CSH as a framework for guiding inquiry and reflection (Ulrich and 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 2021b). Each interview took place remotely and lasted between 45 min and 1 h. 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 1). The intention of this approach was to identify participants from whom a breadth of ideas concerning agroecology's role in

Table 1 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 co-operatives. The organisation has had recent involvement in a report outlining the role of agroecology in Scottish farming.	Male
C	Academic	Researching sustainable food systems with a focus 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
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 a regenerative farming group in Scotland, promoting knowledge exchange and agroecology.	Female
K	Crofter	Crofter[2] with interest in agroecology and its implications for food and farming system change in Scotland.	Female

[2] 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 2021a).

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 see it now, and farming as they believe 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 were 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 2, 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.

Findings

Table 2 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.

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).

Table 2 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 system's conditions of success?	• Farmers (A, H, J) • Landlords (E) • Retailers/buyers (A, H) • Policymakers (F, G, J)	• Consumers (H) • Buyers/retailers (A, H) • 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)

Table 2 (continued)

Source of Influence	Boundary Question	Second Order Theme	
		Farming as it 'is'	Farming as it 'ought to be'
Knowledge	Who provides/ought to provide experience and expertise?	• Farmers (D, G, K) • Agronomists/advisors (D, G) • Farming based organisations/research institutes (A, B, F, G) • Books, online resources, and events (A, G)	• Farmers (A, C, D, E, F, G, K) • Farming based organisations/research institutes (A, B, C, D, F, 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) • 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)

Table 2 (continued)

Source of Influence	Boundary Question	Second Order Theme	
		Farming as it 'is'	Farming as it 'ought to be'
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)
	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)

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).

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).

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 (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, participants 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 crofting 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, more diversity of integration (Participant A).

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 2022).

…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.

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, F, H 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.

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.

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.

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 coms, 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).

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 greater 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 cooperative 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.

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).

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 recognising 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).

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*[1] or something like that (Participant E).

Discussion

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; a 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 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 and Friel 2019). An example described in this study was the requirement for increased consumer ability and receptiveness to pay 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 (Altieri et al. 2017).

---

[1] 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.

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; 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 taken 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 (Ulrich 2003). We therefore do not perceive this to be a major methodological challenge.

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 and McIntyre-Mills 2018; Riswanda, McIntyre-Mills and Corcoran-Nantes 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 suppliers, 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.

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.

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 and 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.

Authors' contributions The main text of the manuscript was written by Matthew Hutcheson. The manuscript was reviewed by Alec Morton, Shona Blair, and Matthew Hutcheson.

Data Availability Not applicable.

Declarations

Ethical approval Ethics approval for this research was granted by the Management Science Ethics Committee at the University of Strathclyde.

Competing interests The authors declare that they have no competing interests.

References

Algraini S, McIntyre-Mills J (2018) Human Development in Saudi Education: a critical systemic Approach. Systemic Pract Action Res 31(2):121–157. https://doi.org/10.1007/s11213-017-9432-9

Altieri MA, Nicholls CI, Montalba R (2017) Technological approaches to sustainable agriculture at a crossroads: an agroecological perspective. Sustainability 9(3):349

Checkland P (1993) Systems thinking, Systems Practice. John Wiley & Sons Ltd, West Sussex, England

Checkland P (2000) Soft systems methodology: a thirty year retrospective. Syst Res Behav Sci 17(S1):S11–S58

Cleland D, Wyborn C (2010) A reflective lens: applying critical systems thinking and visual methods to eco-health research. EcoHealth 7(4):414–424. https://doi.org/10.1007/s10393-010-0362-6

Cole LJH, Eory JP, Karley V, Hawes AJ, Walker C, Watson RL (2021) C. A. *The potential for an agroecological approach in Scotland: policy brief*. Retrieved from

Dehghan Nayeri M, Khazaei M, Alinasab-Imani F (2020) The critical heuristics of iranian Banking Credit System: analysis of the antithetical opinions of the beneficiaries. Systemic Pract Action Res 33(3):363–392. https://doi.org/10.1007/s11213-020-09524-x

Donaires OS (2006) A critical heuristic approach to the establishment of a software development process. Systemic Pract Action Res 19(5):415–428. https://doi.org/10.1007/s11213-006-9033-5

Dumont AM, Wartenberg AC, Baret PV (2021) Bridging the gap between the agroecological ideal and its implementation into practice. A review. Agron Sustain Dev 41(3). https://doi.org/10.1007/s13593-021-00666-3

Gadsby EW, Wistow G, Billings J (2022) A critical systems evaluation of the introduction of a 'discharge to assess' service in Kent. Crit Soc Policy. https://doi.org/10.1177/02610183211065028

Gates EF (2018) Toward valuing with critical Systems Heuristics. Am J Evaluation 39(2):201–220. https://doi.org/10.1177/1098214017703703

Jackson MC (2009) Fifty years of systems thinking for management. J Oper Res Soc 60(Suppl 1):S24–S32

Jackson MC, Keys P (1984) Towards a system of systems methodologies. J Oper Res Soc 35(6):473–486

Kish K, Mallery D, Yahya Haage G, Melgar-Melgar R, Burke M, Orr C, Larson J (2021) Fostering critical pluralism with systems theory, methods, and heuristics. Ecol Econ 189. https://doi.org/10.1016/j.ecolecon.2021.107171

Klocker Larsen R (2011) Critical systems thinking for the facilitation of conservation planning in philippine coastal management. Syst Res Behav Sci 28(1):63–76. https://doi.org/10.1002/sres.1045

Lal R (2001) Soil degradation by erosion. Land Degrad Dev 12(6):519–539

Lampkin N, Pearce B, Leake A, Creissen H, Gerrard CL, Gerling R, Smith L (2015) The role of agroecology in sustainable intensification.

Lawrence M, Friel S (2019) Healthy and sustainable food systems. Routledge

Levidow L, Pimbert M, Vanloqueren G (2014) Agroecological Research: conforming—or transforming the Dominant Agro-Food Regime? Agroecology and Sustainable Food Systems 38(10):1127–1155. https://doi.org/10.1080/21683565.2014.951459

Levin L, Gewirtz S, Cribb A (2017) Shared decision making in israeli social services: social workers' perspectives on policy making and implementation. Br J Social Work 47(2):507–523. https://doi.org/10.1093/bjsw/bcw024

Lozada LMK (2022) A. *The adoption of agroecological principles in Scottish farming and their contribution towards agricultural sustainability and resilience*. Retrieved from

Lyons-White J, Mikolo Yobo C, Ewers RM, Knight AT (2022) Understanding zero deforestation and the high Carbon Stock Approach in a highly forested tropical country. Land Use Policy 112. https://doi.org/10.1016/j.landusepol.2021.105770

Manduna W, Goede R, Drevin L (2022) Incorporating various perspectives in using instant messages in teaching programming: a critical system thinking perspective. Syst Res Behav Sci 39(5):947–961

Mejía A, Mariño JP, Molina A (2019) Incorporating perspective analysis into critical thinking performance assessments. Br J Educ Psychol 89(3):456–467. https://doi.org/10.1111/bjep.12297

Mirhosseini SS, Ramezani M, Khazaei M, Azar A (2021) Exploring and analysing the risks and challenges of implementing ERP systems: critical system thinking. Int J Inform Syst Change Manag 12(3):234–258

Nicholls CI, Altieri M, Vazquez L (2016) Agroecology: principles for the Conversion and Redesign of Farming Systems. J Ecosys Ecograph S 5:010. https://doi.org/10.4172/2157-7625.S5-010

Riswanda, McIntyre-Mills J, Corcoran-Nantes Y (2017) Prostitution and Human Rights in Indonesia: a critical systemic review of policy discourses and scenarios. Systemic Pract Action Res 30(3):213–237. https://doi.org/10.1007/s11213-016-9393-4

Scottish Government (2021a) *National Development Plan for Crofting*. Retrieved from https://www.gov.scot/publications/national-development-plan-crofting/documents/

Scottish Government (2021b) *Women in Agriculture research: progress report – 2020–2021*. Retrieved from https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2021/12/women-agriculture-research-progress-report-2020-21/documents/women-agriculture-research-progress-report-2020-21/women-agriculture-research-progress-report-2020-21/govscot%3Adocument/women-agriculture-research-progress-report-2020-21.pdf

Scottish Government (2022) *Scottish Farm Business Income Estimates 2020–2021*. Retrieved from https://www.gov.scot/binaries/content/documents/govscot/publications/statistics/2022/03/scottish-farm-business-income-annual-estimates-2020-20212/documents/scottish-farm-business-income-estimates-2020-2021/scottish-farm-business-income-estimates-2020-2021/govscot%3Adocument/scottish-farm-business-income-estimates-2020-2021.pdf

Simbolon J (2017) Critical Systems thinking review on decentralized drinking Water Management in Nauli City, Indonesia. Syst Res Behav Sci 34(5):643–653. https://doi.org/10.1002/sres.2490

Tavella E (2016) How to make Participatory Technology Assessment in agriculture more participatory: the case of genetically modified plants. Technol Forecast Soc Chang 103:119–126. https://doi.org/10.1016/j.techfore.2015.10.015

Ulrich W (2003) Beyond methodology choice: critical systems thinking as critically systemic discourse. J Oper Res Soc 54(4):325–342. https://doi.org/10.1057/palgrave.jors.2601518

Ulrich W, Reynolds M (2010) Critical systems heuristics. In *Systems Approaches to Managing Change: A Practical Guide* (pp. 243–292)

van der Linde S, Goede R (2021) From Kant's critique of pure reason, to Action Research in improving the programming skills of students. Systemic Pract Action Res 34(4):419–440. https://doi.org/10.1007/s11213-020-09543-8

Venter C (2019) A critical Systems Approach to Elicit User-Centric Business Intelligence Business requirements. Systemic Pract Action Res 32(5):481–500. https://doi.org/10.1007/s11213-018-9468-5

Venter C, Goede R (2018) A Report and Reflection on an application of critical Systems practice to improve a Business Intelligence System's business requirements. Syst Res Behav Sci 35(5):548–563. https://doi.org/10.1002/sres.2565

Wezel A, Bellon S, Doré T, Francis C, Vallod D, David C (2009) Agroecology as a science, a movement and a practice. A review. Agron Sustain Dev 29(4):503–515

Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, Wood A (2019) Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet 393(10170):447–492

Williams T (2008) Management Science in Practice. John Wiley & Sons, Ltd., West Sussex