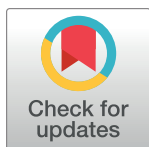


RESEARCH ARTICLE

Transformative action towards regenerative food systems: A large-scale case study

Sam J. Buckton¹, Ioan Fazey^{1*}, Bob Doherty², Maria Bryant^{3,4}, Steven A. Banwart^{5†}, Esther Carmen^{1,6}, Annie Connolly^{4,7}, Katherine Denby⁸, Ian Kendrick^{9,10,11}, Bill Sharpe¹², Ruth N. Wade¹³, Peter Ball², Sarah Bridle¹, Grace Gardner^{4,14}, Anthonia James^{1,15}, Belinda Morris², Sophie Stewart², Myles Bremner¹⁶, Pippa J. Chapman¹⁷, Juan Pablo Cordero¹, Henk Geertsema¹⁸, Nicola Nixon⁴, Eugyen Suzanne Om¹, Maddie Sinclair^{4,19}, Jan Thornton²⁰, Christopher Yap²¹, Dave Arnott²², Michelle Cain²³, Ulrike Ehgartner², Ben Fletcher², Jack Garry⁴, Corinna Hawkes^{21,24}, Alana Kluczkowski⁸, Rebecca Lait², Adrian Lovett²⁵, Kate E. Pickett^{4,26}, Melanie Reed²⁷, Nathan Atkinson²⁷, Fiona Black²⁸, Mark Blakeston²⁹, Wendy Burton⁴, Margaret Anne Defeyter³⁰, Naomi Duncan³¹, Glynn Eastwood²⁸, Ruth Everson³², Angelina Frankowska²³, Tim Frenneux³³, Dave Gledhill³⁴, Sian Goodwin²⁵, Harry Holden³⁵, Helen Ingle³², Allison Kane³⁶, Rebecca Newman¹, Christine Parry³⁷, Victoria Robertshaw³⁸, Tom Scrope³⁹, Philippa Sellstrom³², Stephanie Slater⁴⁰, Kim Smith^{21,41}, Ruth Stacey⁴², Gary Stott⁴³, Alastair Trickett⁴⁴, Jessica Wilson⁴⁵



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1 Department of Environment and Geography, University of York, York, United Kingdom, **2** School for Business and Society, University of York, York, United Kingdom, **3** Hull York Medical School, University of York, York, United Kingdom, **4** Department of Health Sciences, University of York, York, United Kingdom, **5** School of Earth and Environment, University of Leeds, Leeds, United Kingdom, **6** Social, Economic and Geographic Sciences, The James Hutton Institute, Aberdeen, United Kingdom, **7** The Food Foundation, London, United Kingdom, **8** Centre for Novel Agricultural Products (CNAP), Department of Biology, University of York, York, United Kingdom, **9** Metaphorum, Huddersfield, United Kingdom, **10** H3Uni, Glenrothes, United Kingdom, **11** Royal Society of Arts, London, United Kingdom, **12** International Futures Forum, Fife, United Kingdom, **13** School of Biology, University of Leeds, Leeds, United Kingdom, **14** Public Health Department, Newcastle City Council, Newcastle upon Tyne, United Kingdom, **15** The York Policy Engine, The Research, Innovation, & Knowledge Exchange Directorate, University of York, York, United Kingdom, **16** Bremner & Co, Kineton, United Kingdom, **17** School of Geography, University of Leeds, Leeds, United Kingdom, **18** Country Land and Business Association, London, United Kingdom, **19** School of Health & Wellbeing, University of Glasgow, Glasgow, United Kingdom, **20** Yorkshire Food, Farming & Rural Network, Yorkshire Agricultural Society, Harrogate, United Kingdom, **21** Centre for Food Policy, City St George's, University of London, London, United Kingdom, **22** North York Moors National Park Authority, Helmsley, United Kingdom, **23** Cranfield Environment Centre, School of Water, Energy and Environment, Cranfield University, Cranfield, United Kingdom, **24** Division of Food Systems and Food Safety, Food and Agriculture Organization of the United Nations, Rome, Italy, **25** Good Food York, York, United Kingdom, **26** Leverhulme Centre for Anthropocene Biodiversity, University of York, York, United Kingdom, **27** Rethink Food, Leeds, United Kingdom, **28** The Halifax Academy, Halifax, United Kingdom, **29** Grow Yorkshire, York and North Yorkshire Combined Authority, United Kingdom, **30** Department of Social Work, Education and Community Wellbeing, Northumbria University, Newcastle, United Kingdom, **31** Chefs in Schools, London, United Kingdom, **32** Public Health, North Yorkshire Council, Northallerton, United Kingdom, **33** York & North Yorkshire Local Enterprise Partnership, Northallerton, United Kingdom, **34** 1790 Creative, Wheldrake, United Kingdom, **35** Springfield Agri, Springfield Farm Business Park, Harrogate, United Kingdom, **36** Deliciously Yorkshire, The Regional Agricultural Centre, Harrogate, United Kingdom, **37** AB Agri Ltd, Peterborough, United Kingdom, **38** Green Street Pioneers, West Yorkshire, United Kingdom, **39** Soil Benchmark Ltd, Northallerton, United Kingdom, **40** School Food Matters, London, United Kingdom, **41** TastEd, Coleby, Lincoln, United Kingdom, **42** Healthy Schools Programme, Energy Team, Property Services, North Yorkshire Council, Northallerton, United Kingdom, **43** Community Shop CIC, Tankersley, Barnsley, United Kingdom, **44** Trickett Farming Ltd, Leeds, United Kingdom, **45** Public Health, Sheffield City Council, Sheffield, United Kingdom

† Deceased.

* ioan.fazey@york.ac.uk

Original material (post-it notes etc.) is stored on a number of murals in FixOurFood's Mural (<https://www.mural.co/>) account. Data are available from fixourfood@york.ac.uk or the University of York Open Research team (lib-open-research@york.ac.uk) for researchers who meet the criteria for access to confidential data.

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Abstract

We urgently need to foster regenerative food systems that mutually reinforce human and ecological health. However, we have limited understanding of the action pathways that could encourage the emergence of such systems. Here we report on an extensive Three Horizons futures process, conducted with diverse participation from food system researchers and practitioners, to identify core domains of action for transforming the food system of Yorkshire, UK, towards a regenerative future. After establishing the contrast between the current degenerative and envisioned future regenerative food system, six core action domains were identified that require support to enable transformation: 1) enhancing supply chain connectivity and innovation to support diverse hybrid business ecosystems; 2) scaling environmentally beneficial and regenerative farming; 3) empowering citizens to reshape food demand; 4) providing trusted, accessible knowledge support for standards and incentives; 5) supporting schools and young people as drivers of long-term change; and 6) ensuring coordination and mutual support across domains. Our results highlight the importance of efforts to cohere synergic action, ambitious visioning, and addressing issues of power. Overall, our study sets an ambitious standard for co-developing action priorities to encourage regenerative futures.

Author summary

We urgently need to foster regenerative food systems that mutually reinforce human and ecological health. However, we have limited understanding of the kinds of actions that could help such systems to emerge. Here we report on an extensive 'Three Horizons' futures process, conducted with diverse participation from food system researchers and practitioners, to identify core domains of action for transforming the food system of Yorkshire, UK, towards a regenerative future. After establishing the contrast between the current degenerative and envisioned future regenerative food system, six core action domains were identified that require support to enable transformation: 1) enhancing supply chain connectivity and innovation to support more diverse, purpose-led businesses; 2) scaling environmentally beneficial and regenerative farming; 3) empowering citizens to reshape food demand; 4) providing trusted, accessible knowledge support; 5) supporting schools and young people as drivers of long-term change; and 6) ensuring coordination and mutual support across domains. Our results highlight the importance of efforts to cohere actions with impacts greater than the sum of their parts, ambitious visioning, and addressing issues of power. Overall, our study sets an ambitious standard for co-developing action priorities to encourage regenerative futures.

Introduction

Today's dominant food systems produce highly problematic outcomes for people and planet. They are the leading cause of global biodiversity loss and a major contributor to climate change and pollution, leave billions with poor dietary health, cause conflict, encourage spread of pathogens, and create major power imbalances [1–4]. As such there is growing recognition that marginal improvement of existing food systems is insufficient. Instead, extensive and

by North Yorkshire Council. Allison Kane is Business Development Manager at Deliciously Yorkshire and a FixOurFood Commissioner. Tom Scrope is the co-founder and CEO of Soil Benchmark. Kim Smith is a Trustee of TastEd. Jessica Wilson was employed by Sheffield City Council.

deep transformation across the many facets of food systems is required [1,5,6]. Transformation involves going beyond changing technologies, policies and behaviors, to include change in underlying structures, power relations, beliefs, values, paradigms and worldviews of unsustainable systems [7–9].

A powerful orientation for such transformation in food systems is towards regenerative patterns, dynamics and cultures [5,10–12]. Being ‘regenerative’ can encompass a range of aims, practices and outcomes that mean different things to different people [13], but for the purpose of this article we refer to regenerative systems as maintaining positive reinforcing cycles of wellbeing both within and beyond themselves, especially between humans and wider nature, such that ‘life creates conditions conducive to life’ [13,14]. Conceptually, regenerative systems can be considered to go beyond simply reducing anthropogenic harm to acceptable levels, to actively ‘spiraling up’ social and ecological health, and aim to overcome failures of dominant mindsets around commodification, GDP-based economic growth, and separation of humans from nature [5,12,13,15,16]. The regenerative movement is well-established in agriculture, where its interpretations are diverse although its focus is primarily on regenerating soil health that in turn supports delivery of ecosystem services [17–20]. Regenerative *food systems*, however, would need to consider regenerative dynamics across, for example, models of governance, business and education, in addition to farming [5,10]. While interest in transforming food systems is growing, there has been very limited critical analysis of *how* such change at scale can be brought about [21,22].

This paper aims to understand how transformation to regenerative futures could be supported in a real-world large-scale food system. The work focuses on the food system of the extensive 15,420 km² Yorkshire and Humber region (hereafter abbreviated to ‘Yorkshire’) in the UK, with a human population of around 5.5 million. Yorkshire has a diversity of soils, land cover and farming systems (Fig 1), extends across urban and rural environments (Fig 1), and contains the highest concentration of food and drink businesses in the UK [21]. Yorkshire is also a hotbed of food system innovation, as highlighted by a number of recent local food strategies and action plans [23–26], and its networks of innovative farmers and food and drink businesses, such as Yorkshire Agricultural Society’s Farmer Scientist Network [27], Grow Yorkshire [28], and Deliciously Yorkshire [29]. Yorkshire’s food system also shares many challenges with other food systems, such as high rates of food insecurity [30]. These features make Yorkshire a useful case for establishing lessons about regional-scale food system change and well-suited to participatory processes drawing on a diversity of innovative actors, and explains the county’s selection as the focus of the FixOurFood research program [21].

Our work used an in-depth multi-stakeholder co-creation approach using the Three Horizons (3H) futures process [31] (Fig 2), with multiple surveys and workshops engaging 114 experts from three food subsystems spanning production to consumption: 1) agriculture; 2) food economies; and 3) food in schools and early years settings. The results depict what participants identified as the contrast between current systems and normative ideas of what a radically different desired future food system should look like, and the interrelated domains of action needed to support the desired systemic shift.

Results

Current challenges, desired futures, and value contrasts

Participants identified positive aspects of the current Yorkshire food system, such as family-run farms with a long-term stewardship approach and a Yorkshire artisan food identity that has potential to strengthen rural food economies. Yet the current system was perceived by most to be degenerative in some form, reinforcing ecological degradation, social

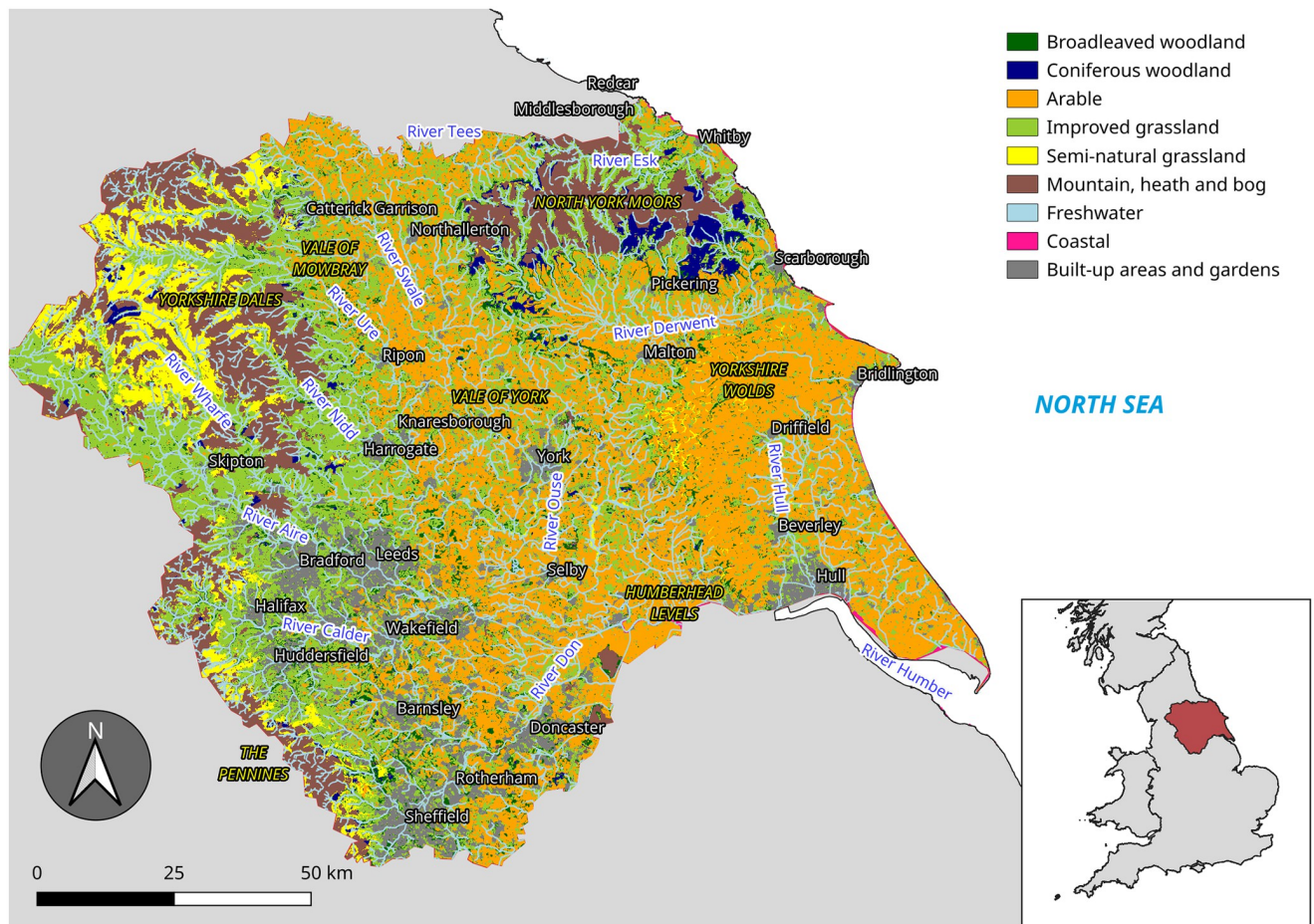


Fig 1. Land use map of the Yorkshire region, UK. The original pixel scale is 25 m. Image produced using AgriFoodPy [32] and QGIS, based upon Land Cover Map 2023 © UKCEH 2024. Contains Ordnance Survey data © Crown Copyright 2007, License number 100017572.

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marginalization and inequalities, eroding human health and wellbeing, and with economic power held by several large retail, processing and agri-tech companies, limiting agency of smaller purpose-led enterprises (Fig 3, Table 1). These problems were thought to be perpetuated by mindsets focused on profit and efficiency at the expense of ecological health and resilience, lack of public awareness and skills around better food, lack of political leadership and agency or resources for transformation, and a constant environment of crisis that was discouraging long-term sustainable thinking and behavior (Fig 3, Table 1).

In contrast, the envisioned system was considered to be much more regenerative, including greater localization, honoring of regional food identity, greater biological and cultural diversity, equality of access to food, agency to produce food regeneratively, and public reconnection to nature and food production that encouraged caring attitudes (Fig 3, Table 2). It was envisioned by participants as having thriving regenerative farming and supported by holistic and ambitious government and business policy. It would be contributing to high regional self-sufficiency, resilience, biodiversity and carbon sequestration, and affordable nutritious food for all (Fig 3, Table 2).

The current and envisioned food systems are underpinned by contrasting values and world-views (Table 3). For instance, in the desired future: food is embraced for its multifaceted social

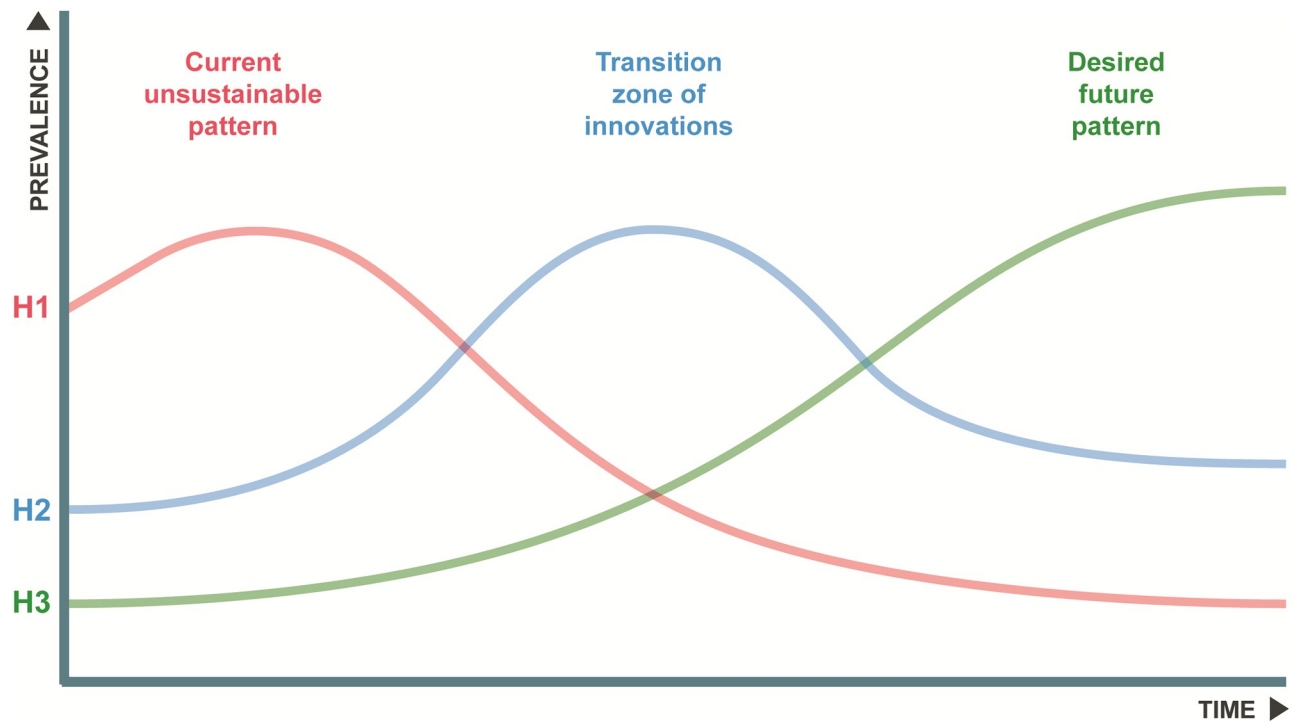


Fig 2. The Three Horizons framework. In this framework, the future is viewed as three horizons, or societal patterns. Horizon 1 (H1) is the pattern that dominates the present, but which is declining as many aspects of it—ways of working, values, assumptions, technologies and so on—increasingly become less fit for purpose as the wider environment changes. Horizon 3 (H3) then represents an envisioned, radically different future—the sense of what a collective wants to bring into being. Horizon 2 (H2) is the transitional zone where actions are strategically oriented to help create space for the longer-term third horizon to emerge. The scaling used in the graph is not intended to be taken literally, but rather for rough qualitative comparison. ‘Prevalence’ describes the relative prevalence of a horizon in the food system (e.g. the amount of resources it holds or transmits, or the proportion of human activity taking place that is related to the horizon). Time flows from left to right: the present is found where H1 is dominant, and all information to the right of this is in the future. Figure originally created in Mural (<https://www.mural.co/>) and rendered by Dave Gledhill of 1790 Creative (<https://autografic.art/>).

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benefits rather than typically being viewed in more utilitarian terms of nutrition and fuel; there are appropriate financial rewards for regenerating and maintaining ecosystem services in farming; and economic power is distributed rather than concentrated (Table 3).

Action needed to support transformation

The contrast between current and envisioned future food systems (Fig 3, Tables 1–3) enabled in-depth exploration, in systemic terms, of the kinds of existing and new initiatives that could support a transformational shift and avoid reinforcing the status quo. Six core domains of action and policy were identified that were deemed to provide critical entry points for cohering change to support transformation. Each of the domains of action—a cluster of many different reinforcing initiatives—would need support and cohering to build momentum, support disruption of the current system, and enable a new, envisioned pattern of activities to emerge.

1. Enhance supply chain connectivity and innovation

The first action domain identified was a need to establish and strengthen new supply chain platforms and networks that can support hybrid businesses generating environmental and social benefits beyond profit. This would require reconfiguring supply chains to support more

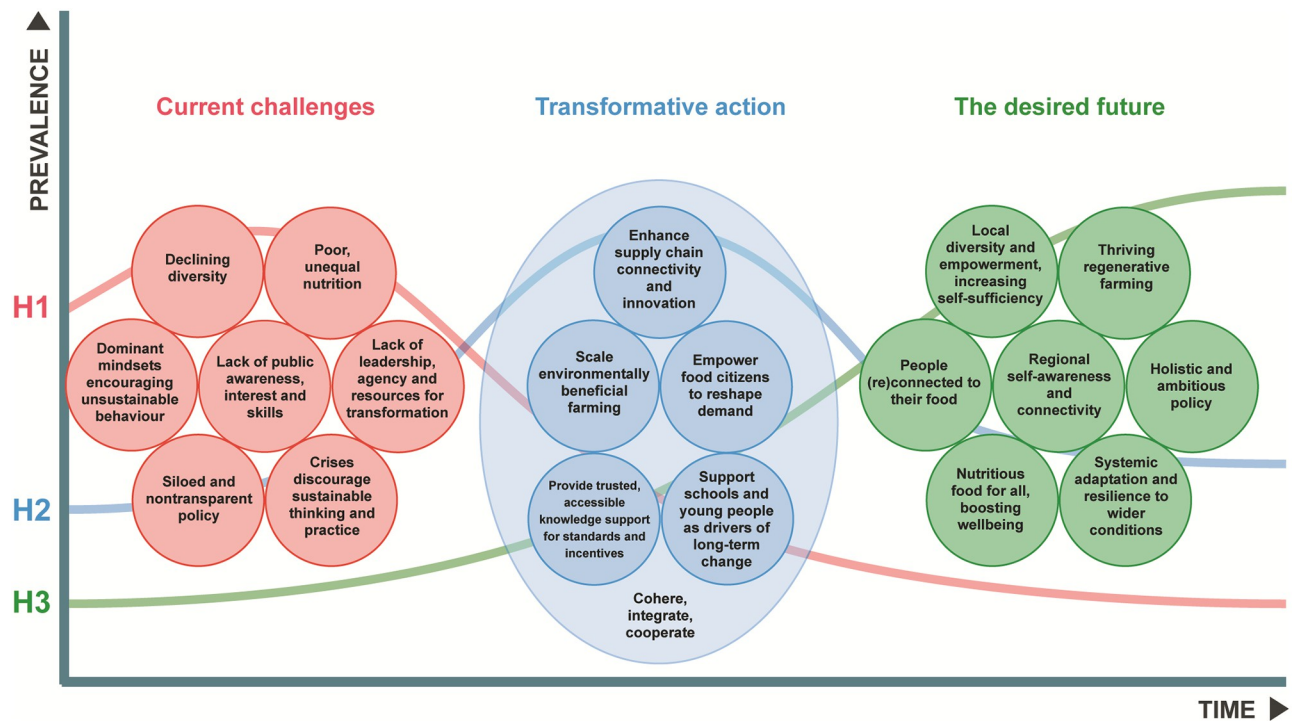


Fig 3. Three Horizons map of current Yorkshire food system challenges (Horizon 1, H1), the desired regenerative future food system (Horizon 3, H3), and key domains of action for supporting the transformation from H1 to H3 (Horizon 2, H2). The scaling used in the graph is not intended to be taken literally, but rather for rough qualitative comparison. 'Prevalence' describes the relative prevalence of a horizon in the food system (e.g. the amount of resources it holds or transmits, or the proportion of human activity taking place that is related to the horizon). Time flows from left to right: the present is found where H1 is dominant, and all information to the right of this is in the future. The exact placement of the circles vertically and horizontally is not intended to reflect differences in prevalence or time—the important aspect is the circles' association to a particular horizon. Figure originally created in Mural (<https://www.mural.co/>) and rendered by Dave Gledhill of 1790 Creative (<https://autografic.art/>).

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direct sales, local and seasonal sourcing (e.g. via dynamic food procurement platforms and food hubs), and more generally enhancing connections between food system actors (including stronger farmer sharing networks), helping to move beyond innovation in isolation by bringing different actors together to develop shared solutions to challenges. As emergency responses to acute food insecurity, such supply chains and networks could redirect surplus and otherwise wasted food to food banks and other food access structures [33,34]. Inspiring alternative food and innovation networks were pointed out as already active in Yorkshire, such as Food Circle York (a social enterprise bringing together a community of customers and organic and regenerative farmers, growers and producers, with twice-weekly markets in York) [35] and Yorkshire Agricultural Society's Future Farmers of Yorkshire (a platform for innovative farmers, vets and industry supporters in Yorkshire that runs conferences and other large-scale events, workshops, mentoring schemes and industry visits) [36], providing opportunities to learn from, replicate and scale up innovative practice, and share ideas and skills.

This action domain has potential to support a fundamental shift in power and agency towards a diversity of marginalized food system actors with a more regenerative ethos, disrupting current patterns of relatively uniform and unequal food procurement. It would support value shifts towards more networked, cooperative action, and the accessibility and convenience of healthy and sustainable food. Bringing multiple actors and system parts together to work cooperatively, rather than working in silos, would enable pooling of resources, sharing risk across partnerships and making investment more attractive, as well as facilitating peer-to-

Table 1. Challenges in the current Yorkshire food system that make it degenerative and inhibit transformation to a regenerative system, according to Three Horizons participants.

Challenge	Explanation
Declining diversity	Biodiversity is declining particularly as a result of harmful farming practices, impairing ecosystem functioning and the richness of people's experience of nature. Meanwhile, innovation and organizational diversity (e.g. of producers and sellers) are limited, and diverse smaller enterprises on local high streets are failing under the dominance of big food retail.
Poor, unequal nutrition	There is widespread and rising food insecurity, food poverty, and inequality of dietary nutrition and health. The relative availability, accessibility and affordability of ultra-processed food and food high in fat, sugar and salt is contributing to an epidemic of malnourishment and obesity, with those on lower incomes disproportionately affected. Unhealthy diets are being exacerbated by advertising and the food environment surrounding schools (e.g. due to the prevalence of fast food outlets).
Dominant mindsets encouraging unsustainable behavior	In the food system overall there is often a narrow focus on profit, price, efficiency and convenience, which pushes healthy nutrition and environmental wellbeing low down on people's agendas. In farming there is a deep-seated 'conventional' farming mindset focused on producing high yields at the expense of ecological health and resilience. This contributes to a degenerative reinforcing cycle, whereby high inputs (e.g. fertilizer) and short rotations can reduce soil health, making farmers even more dependent on high inputs to maintain yield, further degrading soil.
Lack of public awareness, interest and skills	A lack of holistic understanding and interest around food drives degenerative dynamics. This is apparent in many schools, where food's social, environmental and nutritional importance is under-appreciated with school meals under-funded, food education insufficiently holistic, school food standards weakly enforced, and high levels of food wastage. Stressful school dining environments contribute to students developing negative attitudes towards school food. More generally there is a lack of public food awareness—including an understanding of what a healthy or environmentally friendly diet is, how food is produced, and the costs of food production—and skills (e.g. cooking with seasonal produce).
Lack of leadership, agency and resources for transformation	There has been a lack of political leadership, agency and resources for transforming the food system and implementing regenerative practice. There is insufficient agency particularly at local or small scales to enact major positive change, given the concentration of power in a small handful of food retail and processing businesses (e.g. Tesco, Sainsbury's, Asda, Morrisons, Arla Foods, Nestlé, etc.) and high costs constraining SMEs' ability to invest, for instance. For schools, healthier and more sustainable food is harder for institutions to access, whilst farmers have little incentive or support to transform their practice. In general, there was felt to be insufficient skills, tools and resources to facilitate healthy eating practices.
Siloed and nontransparent policy	Policy and organizations lack joined-up thinking and transparency, and policies are typically reactive, siloed and disjointed. This includes limited transparency in land governance, and organizations' asset use tends to be for isolated purposes, so skills and infrastructures are under-utilized.
Crises discourage sustainable thinking and practice	The environment of stress and crisis discourages long-term sustainable thinking and practice. For example, product shortages (due to factors such as COVID-19, Brexit and the Russo-Ukrainian war) encourage the procurement of more unhealthy processed, cheap school food, and transforming farming practices can be seen as financially too risky, with the hardships associated with farming discouraging young people from viewing it as a sustainable career. Labor shortages place further pressure on farms.

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Table 2. Themes of the desired future regenerative Yorkshire food system envisioned by Three Horizons participants.

Theme	Explanation
Local diversity and empowerment, increasing self-sufficiency	The food system has high local diversity and empowerment, with a thriving diversity of small organizations (e.g. producers, processors and retailers) and urban and small farms. These organizations are supported by fair and inclusive market arrangements such as dynamic food procurement platforms for supplying the public sector, as well as new, more direct supply chains between regenerative farmers, schools and businesses. This is contributing to high resource circularity and self-sufficiency, with lower reliance on food imports and less food waste.
Thriving regenerative farming	Viable regenerative farming practices have been embraced as the inspiring choice, not least due to a culture of sharing best practice between farmers, and farmers are well-paid via supply chains to produce food regeneratively. A result of these supply chains is that regeneratively sourced school food has a positive environmental impact. Young people and innovators are motivated and well-supported to enter the farming sector, ensuring the sustainability of its workforce. Thanks to the wide range of public services that farms produce in addition to food, we live in biodiverse landscapes, and the food system is carbon-negative.
People (re)connected to their food	People in the food system are empowered, knowledgeable, skilled and engaged, and school students, staff and families have high levels of food literacy, with a reconnection of people to nature integral to education and policymaking. Consumers embrace the opportunities offered by the new food choice realities of more localized and seasonal food sourcing, with a greater proportion of plant-based meals, but also a diversity of new foods (e.g. grain and fruit varieties). Care and appreciation of food and its importance contributes to a zero-waste approach to food.
Regional self-awareness and connectivity	There is high awareness and connectivity of food system actors, including an integrated land use strategy at national and regional levels, and awareness and recognition of good farming practice that is already occurring. Moreover, Yorkshire food is distinctive and desirable across the UK.
Holistic and ambitious policy	Joined-up, long-term policy with a systemic perspective prioritizes healthy, sustainable food, with rewarding of good practice and a right to food enshrined in local and regional policy. School food is understood as integral to the wider food and education system, and there is accordingly clear enforcement and communication of ambitious school food standards. Socio-environmentally responsible business models are the norm.
Nutritious food for all, boosting wellbeing	Healthy neighborhood food environments (foodscapes) support a high proximity of healthy food for all demographics, which is at the heart of a preventative health system. Schools have sufficient resources to provide high-quality food for all, and even support wider community wellbeing via food partnerships and pastoral support. As a result, people in school communities are healthy in body and mind, and the wider wellbeing of producers and food citizens is increasing.
Systemic adaptation and resilience to wider conditions	Farming decisions improve livelihoods and resilience (e.g. to climate change and associated extreme weather events), not only yield, and high international trade standards mean Yorkshire does not externalize impacts when importing. Creativity is thriving from a diversity of perspectives and backgrounds in schools, and developmental evaluation and futures methods are embedded in food system activity to aid adaptation to a complex, uncertain and constantly shifting environment.

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peer learning. Hybrid business models are known to keep value distributed within local food systems, rather than accumulation by the few (e.g. shareholders), reinforcing local agency [36]. By strengthening farmer sharing networks and creating new supply chains, this action domain was considered to have potential to enhance capacity for regenerative farming and resilience to external shocks.

Table 3. Contrast between the values of the current Yorkshire food system and the desired future system, identified by Three Horizons participants.

Current food system value	Future envisioned food system value
Low diversity	High diversity
Healthy and sustainable food is exclusionary	Healthy and sustainable food is universally accessible and affordable
Concentrated power	Distributed power
Actors work in isolation	Actors work in a culture of networking, cooperation and sharing
Reactive policy	Proactive policy
Disjointed policy	Holistic policy
Minimal support for public goods and ecosystem services	Appropriate financial rewards for regenerating and maintaining ecosystem services
Transformation seen as too risky	Transformation seen as essential and inspiring
Good practice talked about but rarely applied	Good practice normalized
Focus on maximizing crop yields at the expense of ecological health and resilience	Profitable farming that also improves social and ecological wellbeing and resilience
Limited public food awareness and skills	High public awareness and connection to food system
People typically have restricted diets	People typically have varied diets that boost nutrition
People used to huge freedom of food choice	People embrace new constraints (but also possibilities) of seasonality, more local sourcing, etc.
Convenience means ultra-processed and fast food	Convenience means fresh local unprocessed food available to all
Food typically viewed in more utilitarian terms of nutrition and fuel	Food embraced holistically for nutrition, culture, social engagement, health, education and environment

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Supporting this domain was thought to require good awareness of where hybrid businesses and networks already exist, as well as proactive attempts to attract funding, support local authorities and other organizations in funding applications, and provide capital for establishing such platforms, hubs, consortia and cooperatives. Care would also be needed to ensure platforms do not have excessive charges that raise prices for consumers or reduce producer incomes, and that they genuinely increase convenience for consumers to purchase food from hybrid businesses (see action domain 3).

2. Scale environmentally beneficial farming

The second action domain is a need for long-term evidence-based policy and market support for scaling environmentally beneficial and regenerative farming. In addition to creating stronger market incentives (e.g. action domain 1), it also requires institutionalizing long-term commitments to scaling up ‘horizontally’ via city and regional-scale councils, partnerships and networks (e.g. Future Farmers [37]) and ‘vertically’ via national-scale policy working with the UK Department for Environment, Food & Rural Affairs (Defra) to ensure an integrated land use strategy and that environment or agri-environment schemes such as Environmental Land Management (ELM) and carbon credits (a system for financing carbon offsetting via land management that reduces, avoids, or removes carbon emissions) genuinely provide sufficient support. It also requires improving farmer-policymaker relationships via constructive dialogue, and getting big players (e.g. large-scale food producers, processors and retailers) on board for system-wide mainstreaming.

A commitment to such scaling was considered important for supporting transformation by ensuring regenerative and other environmentally restorative farming, and associated mindsets, become mainstream rather than remaining as small-scale, isolated innovation. Concerted

action would also support value shifts towards high biological and agricultural diversity, rewards for good practice, farming that focuses on livelihoods and resilience, and more holistic policy. Mainstreaming could have major positive environmental impacts, from increasing biodiversity and capturing carbon, to improving soil and water quality, benefiting both human health and wellbeing.

Education was seen as key. Many courses in agricultural colleges were considered to focus on machinery and yield, with insufficient emphasis on environmental stewardship or nutritional diversity, highlighting a need for more integrative and holistic education that connects food with the wider Earth system. Giving greater recognition to regenerative farming systems was also considered important, such as by designating 'Areas of Outstanding Natural Farming' in areas lacking existing protection (e.g. outside National Parks and National Landscapes, which designate areas of ecological, aesthetic and cultural importance in the UK). Strong farmer networks would be needed to help farmers navigate the complex array of funding schemes for environmentally beneficial farming, alongside scientific evidence to inform regenerative farming systems and demonstrate their economic, environmental and social potential (see action domain 4).

3. Empower food citizens to reshape demand

Empowering food citizens to encourage demand for regeneratively produced food will be critical for transformation to a more regenerative food system. Participants emphasized that changing policy and governance around food production, processing and distribution must coincide with fostering demand for new supplies and forms of food, inspiring the public to lead a culture change in consumption and shifting emphasis to local, seasonal, and zero-waste. Overall, the goal would be to develop a population of empowered and knowledgeable food citizens (re)connected to their food and its origin, to whom transformation to a regenerative food system becomes a meaningful and desirable change.

Four aspects were seen as particularly important in meeting this challenge. First, extensive efforts will be needed to ensure regeneratively produced food is affordable, whilst also giving producers a high proportion of income from the sale price. Second, much greater awareness of the importance of food will be required. Key to this will be improving food literacy of school staff, students and families (see action domain 5). Using urban space for food-growing and twinning urban and rural farms to establish community links could help to reconnect people with where their food comes from. It also requires helping people move away from seeing food only in utilitarian terms by drawing on the fundamental social, cultural and environmental connections between people and food, as happens in family cooking initiatives in schools. Numerous initiatives doing this work to shift consumer mindsets already exist, such as TasteD (which offers teachers support for taste education lessons that bring fresh fruit and vegetables into classrooms) [38], Rethink Food (which provides resources for schools to introduce holistic approaches to growing, cooking and learning about food) [39], Farmer Time (which connects schoolchildren to farmers via live online chats) [40], and Open Farm Sunday (an annual public open day for UK farms) [41]. Third, food retailers can support food waste reduction, e.g. by removing 'use by' date labeling and selling loose unpackaged fruit and vegetables (including 'wonky' produce), which additionally cuts packaging waste [34].

Finally, regeneratively produced food needs to be accessible. This includes ensuring that physical infrastructure of food shopping for regenerative food is appropriate. This might include local rural branches of large supermarkets prioritizing more local produce, or finding ways to increase diversity of local food suppliers (e.g. near schools). Accessibility also needs to be enabled by ensuring appropriate information (e.g. about food's environmental impact, and

clearer brand differentiation for regeneratively produced food) is readily available to consumers, such as through changing the UK Groceries Supply Code of Practice (which sets out how retailers are expected to fairly manage their relationships with suppliers) and food standards.

4. Provide trusted, accessible knowledge support for standards and incentives

Provision of trusted and accessible knowledge, including transparent data, rigorous scientific evidence, and data-sharing networks, is needed to establish food system standards and policy and incentives for good practice, such as for farmers shifting to regenerative agriculture or hybrid businesses. Here, standardized indicators and tools are needed to facilitate comparison and communication of data from different areas and spatial scales, as well as open and accessible data. Too often, data are collated in extractive ways, kept private, and serve vested interests. An open approach to knowledge and data could support value shifts towards networking and sharing, enhanced public awareness of the food system, and a more consistent, common language and coordinated action. Readily available and accessible information would support more agile and reflexive ways of working, helping producers and policymakers respond to changing food system conditions. A number of organizations are already working to support this action domain (e.g. to help farmers maximize the use of soil data, such as Soil Benchmark [42] and Soilmentor [43], or Take a Bite Out Of Climate Change, which shares in accessible ways the scientific consensus about how food and agriculture contribute to climate change [44], with many additional opportunities to build on such initiatives and share data 'beyond the farm gate'.

5. Support schools and young people as drivers of long-term change

Schools and young people will need to be supported to be drivers and advocates of long-term food system change. Schools are major procurers of food and have significant influence on society through education, and young people are often inspirational and passionate leaders of change with interests in realizing long-term shifts in the food system. The action domain is closely related to domain 3 –empowering consumers—but more specifically focuses on schools and young people as this sector provides key opportunities for leveraging change across the whole of the Yorkshire food system.

Support for this action domain will both address immediate and real challenges facing people as they struggle to contend with difficulties in accessing healthy and affordable food while also bringing about cultural shifts. This can be achieved through taking whole school approaches to food, where food is viewed as an intrinsic part of school life, healthy and sustainable food is provided within and outside the school environment, food becomes integral to curricula, and schools and authorities work in partnership with communities, producers and providers. There are many existing exemplars, such as: school caterers increasing children's dietary diversity and intake of locally produced fruit and vegetables; embedding food in curricula; children growing vegetables in school allotments and cooking with them to create tasty and nutritious meals in school; efforts to ensure free school meals; enhancing atmosphere and culture in school dining to improve relationships to food; inviting families in deprived areas to learn to cook from scratch and eat together as a community; involving students and parents or carers in school food decision-making, such as menu co-design, which motivates students to be champions of food system transformation; and more broadly using food as a focus to empower students to be leaders of change.

Supporting the domain requires: engaging school leadership to enhance demand for whole school food approaches; ensuring new approaches are embedded in mandatory school food

standards and via food award schemes; shifting perceptions about the importance of free school meals; influencing national policy to address constraints in funding; free school meal auto-enrolment; and changing schools' contracting and procurement practices to address, for example, barriers to local farmers more directly supplying schools. Overall, a focus on schools and young people can support value shifts towards more holistic perspectives and universality of food access, with sustainable and healthy eating behaviors being carried with students throughout their lives and reflected back in homes and local communities. Through better school food cultures, major food waste reductions are also possible.

6. Cohere, integrate, cooperate

Food system transformation will only happen when different areas of action reinforce each other to help create a new system dynamic. A critical action domain would therefore be to cohere and integrate the other domains, capitalize on opportunities, and reinforce transformative effects (Fig 4). For instance, participants identified that producer- and consumer-led change go hand in hand, that enabling more localized supply chains would support the scaling of regenerative agriculture, and that supporting schools and young people to be drivers of food system transformation sustains future generations of motivated food system workers (Fig 4). Through greater cohering and collaboration, impacts could be amplified, actions for transformation would be more efficient, and opportunities would be provided for collaborative learning about transformation [45]. A critical enabling condition is then having appropriate cross-system modes of governance, monitoring and evaluation to steward large-scale integrated action [46].

Discussion

Our findings highlight major contrasts between the current degenerative and an envisioned regenerative Yorkshire food system (Fig 3, Tables 1–3). The current food system is degenerative in the way it reinforces continued ecological degradation, power imbalances, social marginalization, and erosion of human health and wellbeing. Many other food systems in the UK and beyond are facing similar challenges, including the concentration of economic power by a handful of food retail companies, soil and other environmental degradation from farming, and increasing food poverty [47–51]. In contrast, our Three Horizons participants envisioned a much more regenerative future food system. For example, participants expressed desire for greater localization and honoring of regional food identity, greater biological and cultural diversity, equality of food access, agency to produce food regeneratively, and public reconnection to nature and food production that encourages caring attitudes. These are common signatures of regenerative food systems highlighted elsewhere [5] and echoed in other envisioned food systems in the UK [23,48]. Notably prominent in our study, however, is the identification of underlying mindsets and values driving unsustainable behavior and how these would have been remolded in the envisioned future, thus establishing the transformative shift that actions would have to support (Table 3).

Supporting this shift will not be easy and will require considerable effort to cohere and support diverse action, including for the six critical interrelated domains of action identified by diverse experts from across the food system (Fig 3, Table 4). These domains show how a transitional system can begin to disrupt a status quo and create space for more regenerative and radical innovation to emerge. Our work also highlights the importance of cohering and connecting actions to enable synergic effects, whereby the overall impact is greater than the sum of effects of individual parts in accelerating transformation. In this case, for example, various

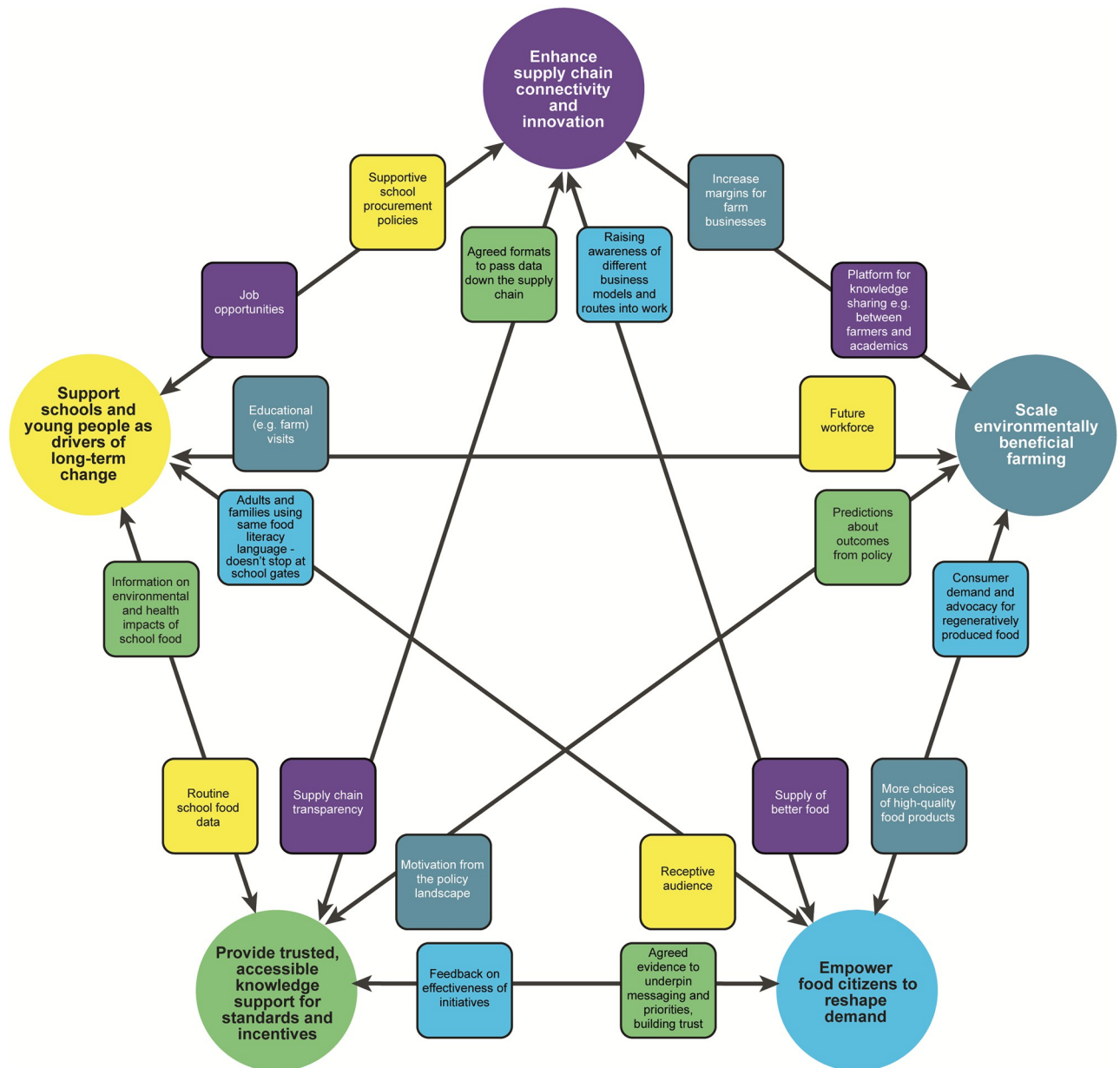


Fig 4. Diagram showing how five action domains strengthen each other to support food system transformation in Yorkshire. Circles represent the action domains, and squares represent how each action domain strengthens another (their color is matched to the action domain they originate from). Figure originally created in Mural (<https://www.mural.co/>) and rendered by Dave Gledhill of 1790 Creative (<https://autografic.art/>).

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pre-existing local food strategies and action plans in Yorkshire [23–26] provide opportunities to elevate transformational efforts if they can be effectively cohered.

This, in turn, needs more effective coordination across local, regional and national policy that enhances local agency and grassroots change. Examples include policies that fund school meals, deliver more effective farming stewardship schemes, and enable dynamic food procurement platforms to be established. Effective cohering will also require new, transformational, forms of organizing and governance [46,52]; support from developmental, empowering,

Table 4. Domains of action identified by Three Horizons participants as necessary for supporting transformation towards a regenerative food system in Yorkshire.

Action domain	Key actions	Why transformative?
1. Enhance supply chain connectivity and innovation	<ul style="list-style-type: none"> Reconfigure supply chains to support more direct sales, local and seasonal sourcing, and redirect surplus or waste food to those in need Strengthen sharing networks (e.g. of farmers to share best practice and resources) Introduce fairer supply chain arrangements for small supplier organizations, such as dynamic food procurement platforms for public sector institutions 	<ul style="list-style-type: none"> Encourages higher diversity of organizations and more distributed power in the food system, disrupting the dominance of several big players Encourages culture of networking and cooperative working Supports actors (e.g. hybrid businesses) led more by values of human and environmental wellbeing than by price, efficiency and convenience Helps to change the identity of convenient food to fresh local unprocessed food rather than ultra-processed and fast food
2. Scale environmentally beneficial farming	<ul style="list-style-type: none"> Institutionalize long-term, evidence-based commitments to scaling environmentally beneficial farming via city, regional-scale and national-scale policy Improve the farmer-policy maker relationship via constructive dialogue Get big players (e.g. large-scale food producers) on board for system-wide mainstreaming Introduce more integrative, holistic education in agricultural colleges that connects food with the wider Earth system Give greater recognition to regenerative farming systems 	<ul style="list-style-type: none"> Commits to making regenerative and other environmentally restorative farming systems (and the mindsets associated with them) truly mainstream rather than remaining as small-scale, isolated innovation Supports value shifts towards high (biological, agricultural and biocultural) diversity, rewards for good practice, farming that focuses on livelihoods and resilience, and more holistic policy Would kickstart regeneration of environmental health, including increasing biodiversity, capturing carbon, and improving soil and water quality, which in turn bring benefits for human health and wellbeing
3. Empower food citizens to reshape demand	<ul style="list-style-type: none"> Inspire the public to lead a culture change in consumption, shifting emphasis to local, seasonal and zero-waste Improve the food literacy of school staff, students and families Use urban space for food-growing and twinning urban and rural farms to establish community links Food retailers should support food waste reduction, e.g. by removing 'use by' date labeling and selling loose unpackaged fruit and veg (including 'wonky' produce) Ensure accessibility and clear visibility (e.g. via labeling) of regeneratively produced food 	<ul style="list-style-type: none"> Works to develop a population of empowered and knowledgeable food citizens to whom a transformation to regenerative food systems becomes a meaningful and desirable change Taps into the deep social, cultural and environmental connections between people and food, moving away from seeing food mainly in utilitarian terms Helps the public to understand and appreciate constraints but also opportunities of new realities of food choice relating to seasonality, more local sourcing, etc.
4. Provide trusted knowledge support for standards and incentives	<ul style="list-style-type: none"> Provide trusted and accessible knowledge support, including transparent data, rigorous scientific evidence, and data-sharing networks, to food system actors transforming their practice, such as farmers shifting to regenerative agriculture or hybrid businesses, as well as policymakers Standardize indicators and tools to facilitate comparison and communication of data from different areas and scales 	<ul style="list-style-type: none"> Approaches knowledge as transparent, dynamic and empowering, rather than gained and hoarded in more extractive, opaque and inaccessible ways that serve vested interests of the status quo Supports value shifts towards networking and sharing, and public awareness of the food system Supports rapid feedback and learning for agile adaptation to food system conditions
5. Support schools and young people as drivers of long-term change	<ul style="list-style-type: none"> Encourage whole school approaches to food (embracing food's educational as well as nutritional value) Involve students and parents/carers in school food decision-making, including menu co-design Embed new approaches in mandatory school food standards and via food award schemes Support accessibility of tasty, healthy food for all via free school meal auto-enrolment Change schools' contracting and procurement practices to address, for example, barriers to local farmers more directly supplying schools 	<ul style="list-style-type: none"> Supports transformation as a sustained, long-term change that gets to the heart of how we learn to relate to food, nature, society and culture Builds up knowledge and skills in younger generations who will carry the makings of a regenerative food system with them well into the future Supports value shifts towards more holistic perspectives of food, high awareness of the food system, and universal accessibility rather than exclusivity of healthy, sustainable food Uses the prominent role of schools in the overall food system (e.g. their substantial throughput of food and universality of provision) to have a major impact in dietary change, improving food equality and waste reduction
6. Cohere, integrate, cooperate	<ul style="list-style-type: none"> Ensure all the action domains are working in tandem towards a shared goal Identify what each action domain can offer to the others to enhance their transformative potential 	<ul style="list-style-type: none"> Amplifies the impact of individual actors Makes transformative action more efficient (e.g. avoiding duplication) Helps actors to understand transformation in a more systemic way

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complexity-aware and transformation-focused modes of evaluation [53]; and transdisciplinary, action-oriented research [46,54].

A good starting point for effective cohering has been the establishment of a new high-profile commission—the FixOurFood Commission [55]—to help drive transformation. The Commission was established as a direct result of this research and involves influential food system actors tasked with building momentum for large-scale food system change in Yorkshire. The six action domains provide a strategic focus for the Commission’s work. A second outcome from our research, driven particularly by action domains 2 and 4, has been the installation of a co-designed regenerative farming trial and demonstration platform at the University of Leeds farm, with involvement of a large network of stakeholders, to provide data and evidence informing how to transition to a regenerative farming system [56]. Our work should also directly inform: the ongoing development of regional-scale food strategies, e.g. by North Yorkshire Council [57]; investment priorities of Yorkshire’s mayoral combined authorities (MCAs), including the newly created York and North Yorkshire MCA; and the research priorities of the FixOurFood program more generally [21] as it enters its final year.

Our study sets an ambitious standard for co-developing action priorities to encourage regenerative futures. We suspect that transforming food systems elsewhere in the UK will require a similar combination of producer-led, consumer-led, top-down and bottom-up change, building on pre-existing momentum, and cohering, integration and cooperation, to that highlighted by our study. Moreover, the recent disruption to international food supply chains from climate change [58] and geopolitical crises such as the Russo-Ukrainian War [59] will surely focus attention across the wider UK on efforts for greater food self-sufficiency (the UK currently imports around half of its food [60]), which arose as a key topic in our Yorkshire-focused work.

There were, however, two important limitations of our work that will require further effort and work. First, some of our work struggled to establish a truly radical vision. An ambitious vision is important to guide transformation, help actors reframe a sense of what is possible, and ensure that efforts at change address the underlying worldviews, assumptions and mindsets that hold a current system in place [31]. Establishing genuinely ambitious visions is, however, harder than one might think given that people struggle to imagine something they have not yet experienced [61]. Our vision, for example, could be critiqued for still viewing the environment in utilitarian terms; not sufficiently envisioning a future beyond a growth-focused capitalist mindset [62]; or for having limited vision of how inequalities might have been tackled. Use of visioning tools like the Regenerative Lens (which aims to encourage ambition and alignment to regenerative system concepts in futures practice) [13] or Seeds of Good Anthropocenes (which aims to create optimistic, realistic visions of the future based on identifying and growing ‘seeds’ of pre-existing exemplars of innovative ways of thinking and living) [60], as well as research to support imagination (e.g. Joseph Rowntree Foundation’s Emerging Futures [63]) will therefore be important for any transformational initiative going forwards.

Second, significant efforts were made in our work to honor diverse views and include diverse goals and values, and identify systemic action. Yet the process we undertook did not provide the time and space for detailed work that would be needed to creatively address some of the key dilemmas and tensions involved. This included three key aspects: power, innovation, and trade-offs of farming practices and different diets. Clearly, there are dilemmas around the ‘power’ embedded in the Yorkshire food system, like that held by a handful of large enterprises, such as supermarkets that hold many elements of the current system in place. While the dominance of supermarkets helps to support distribution of food to a large population at low cost due to economies of scale, it can constrain transformation. Our Three Horizons findings also revealed a tension between more bottom-up forms of innovation and change and notions

of disrupting monopolies in the food system (e.g. in action domain 1, ‘Enhance supply chain connectivity and innovation’), and the desire to ‘get big players on board’ for more system-wide impact (e.g. in action domain 2, ‘Scale environmentally beneficial farming’). The trade-offs of different farming practices and different diets must also be further explored to fully understand their impacts on wider ecosystem services. For example, the meat and dairy industry holds significant social, economic and cultural power [64], yet much of its conventional practice will also need to be challenged and downscaled or modified if society is to move towards genuinely regenerative futures [65–67]. The issue is also not straightforward: while there is a growing social movement to reduce meat consumption, integrating livestock is one of the main principles of the regenerative agriculture movement, with farmyard manures key to adding carbon back into the soil and thus helping to restore soil health [17,18,68], and claims that livestock in some regenerative farming systems are carbon-negative [68]. However, livestock are also major contributors to methane emissions [69] and can cause water quality decline [70]. These issues have created tensions between regenerative farmers and the vegan movement, for instance [71]. Thus, while our work began to open up discussion about some of these issues, and set an ambitious overarching direction that had high levels of consensus, much more extensive effort will be needed to find creative ways of working with dilemmas and power imbalances.

Reflecting on our Three Horizons process in light of other applications of this framework, what stands out is our unusually extensive, iterative, multi-step and multi-actor application that integrated results from across multiple food subsystems and considered how action could be systemically cohered. Our approach aligns with recommendations for more second-order, adaptive and reflexive approaches in co-creative research and transformation contexts [72–74], as well as incorporating diverse forms of knowledge in food system transformation research [54,75].

From this approach, we learnt a number of lessons as facilitators. Firstly, the process required high levels of coordination, as well as considerable commitment of time and effort from participants. We found that online platforms, notably Mural (<https://www.mural.co/>)—although many other similar platforms exist—were helpful for collaboratively engaging with large groups of people (e.g. populating Three Horizons maps), especially given the shift to online workshops during the COVID-19 pandemic. However, it was not always easy for participants who were unfamiliar with online meeting forums and collaborative platforms, and poor internet connections particularly for those joining from rural locations impacted their ability to contribute and follow the workshops. Secondly, the process reinforced to us that Three Horizons is an orienting tool: whilst it provides many opportunities for detailed analysis, what participants valued most was that it helped them to work through complexity and distill information down to core messages and narratives. Since applying Three Horizons in this way, we have focused on how food system actors can reinforce one another in service of more regenerative dynamics. While it was outside the scope of our project, there are ways of practicing Three Horizons that focus more on specific, named actors (e.g. organizations, businesses and initiatives) and thus enable even more action-oriented use of the Three Horizons results (e.g. in ‘ambition loops’ to cohere reinforcing action between government policy, business, and civil society [76]) and encourage more direct commitments to action from participants. Nonetheless, our results still provide useful overarching themes, and are being used to strategically orient the work of organizations such as the FixOurFood Commission.

In conclusion, supporting transformation at scale requires cohering and connecting many different disruptive and innovative forms of action while maintaining transformational intent. In this case, six important action domains were identified, focused on supply chains, scaling regenerative farming, empowering consumers, providing open and accessible knowledge,

working with schools and early years settings, and cohering action. Clearly, transformation will require much concerted effort. Yet, through more effective cohering and connecting across different scales, continuing to help reshape the sense of what is possible, and actively attending to power imbalances, the possibility for transformation becomes more tenable. This can be further enhanced with support from transdisciplinary, action-oriented, second-order modes of research to understand how power imbalances might be more effectively navigated, how new ways of organizing and governing can be developed, and how more developmental approaches to evaluation can support and help to drive transformational change.

Materials and methods

Overview

This research aimed to identify and co-create core activities that would begin to support transformation towards a regenerative food system in Yorkshire. It involved working with diverse actors and researchers through a deliberative and adaptive process specifically designed to examine how systemic change can be supported. The methods explain how the research was framed and its approach to knowledge and knowing, followed by the specific methods used. An overview of the process is provided in Fig 5.

Ontological framing

How an issue is framed greatly influences the way research is conducted, including the kind of questions asked and methods [77]. Being explicit about ontological positions—how ‘reality’ is understood—is therefore critical for guiding transdisciplinary research [78]. Our work was carefully framed by four core ontological positions (Table 5).

Food system: Food-related activity was viewed as a complex system, with diverse and dynamic interactions occurring between different system components, including all elements and activities relating to the production, processing, distribution, access, preparation, preservation, consumption, disposal and recycling of food [21,79,80], as well as more broadly between behaviors, technologies, economies, politics, health, environment and society [21,80,81], and the assumptions and worldviews shaping the food system [80].

Transformation: To overcome the many challenges and impacts, many have advocated the need for transformation of food systems [1–4]. We viewed transformation as a process of major, fundamental change, qualitatively distinct to other kinds of change, such as marginal and incremental change, or adjustments or reforms which tend to focus on ‘change to keep things the same’ [22]. Transformations go beyond changing technologies, policies and behaviors within systems to also changing structures, power relations, beliefs, values, paradigms and worldviews [7–9]. As such, to support transformation a different strategic approach is required compared to supporting other kinds of change [22].

Regenerative food systems: Supporting transformation requires clarity about what the transformation is meant to achieve [82]. In this research, the transformational goal was broadly to shift the food system towards one that would be regenerative. We considered such systems to maintain positive reinforcing cycles of wellbeing within and beyond themselves, including between humans and wider nature [13], such that ‘life creates conditions conducive to life’ [14]. Importantly, being regenerative is about going well beyond reducing the harm caused by human activity to acceptable levels [16,83], with a new set of underlying dynamics that result in ‘more good’ rather than simply ‘less bad’, and transformational worldviews and relations of ecological interdependence and mutualism [5,12,13,15,16]. Regenerative food systems apply these ideas to food-related activity, including food production and use, food waste, entrepreneurship, finance, governance, livelihoods, education, and technology [5]. They commonly

Research aim:	how can transformation to a regenerative food system be supported in Yorkshire?
Main questions:	1) What are the challenges in the current Yorkshire food system that make it degenerative and inhibit transformation to a regenerative system? 2) What would a future regenerative Yorkshire food system look and feel like? 3) What current and needed innovations could support transformation to the desired future?
Methods:	Three Horizons (3H) workshops and surveys; other workshops; inductive thematic analysis
Headline stats:	14 months of data collection from Oct 2021 to Dec 2022; 29 FixOurFood researchers involved; 85 wider stakeholders engaged (45 in workshops); 15 workshops (45.25 hours total); c. 1400 initial individual ideas generated, ultimately coded to 19 themes (7 for H1, 7 for H3, 5 for H2)

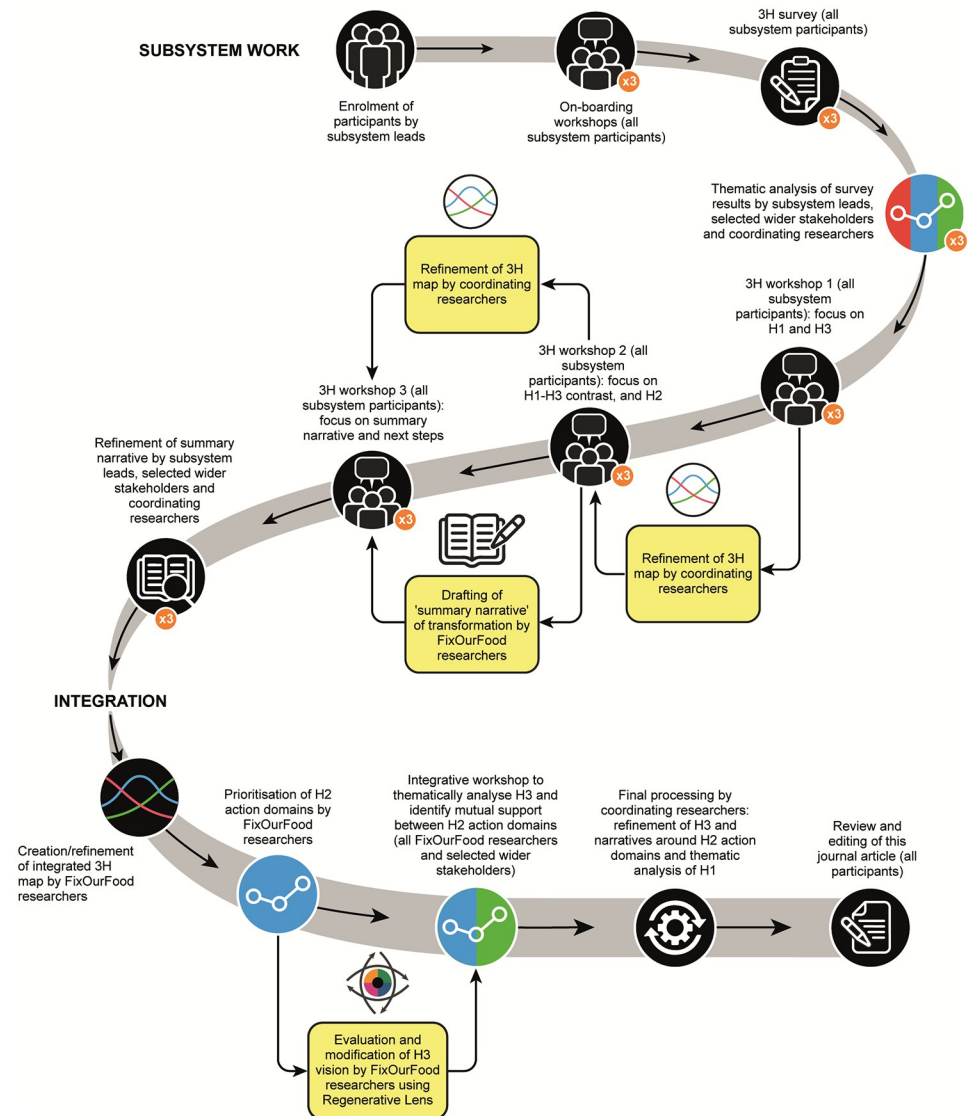


Fig 5. Process diagram for the research underpinning this study. 'Subsystem leads' are FixOurFood researchers coordinating subsystem participants and processes. 'Wider stakeholders' are experts working or studying in their subsystem in the Yorkshire food system who are not FixOurFood-employed researchers. 'Coordinating researchers' are FixOurFood researchers coordinating the entire Three Horizons process. Initial stages worked with FixOurFood researchers and wider stakeholders from three different subsystems of the Yorkshire food system: 1) agriculture, 2) schools and early years settings, and 3) food economies. Findings from these three subsystems were then integrated through further analysis and workshops. Figure originally created in Mural (<https://www.mural.co/>) and rendered by Dave Gledhill of 1790 Creative (<https://autografic.art/>).

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Table 5. The core ontological positions used to frame the research.

Ontological position	Explanation
Food systems	<ul style="list-style-type: none"> Food-related activity viewed as a complex system, with diverse and dynamic interactions occurring between different system components [21,79–81].
Transformation	<ul style="list-style-type: none"> Transformation understood as a major, fundamental change qualitatively distinct from relatively marginal or incremental adjustments or reforms [22], which changes a system's underlying structures, power relations, beliefs, values, paradigms and worldviews [7–9].
Regenerative food systems	<ul style="list-style-type: none"> Transformation envisaged as being towards a 'regenerative food system'. Future food system envisioned as a regenerative system—one that maintains reinforcing cycles of wellbeing within and beyond itself, including between humans and wider nature [13], such that 'life creates conditions conducive to life' [14]. Regenerative food systems seen as encompassing more than just regenerative agriculture, and underpinned by worldviews and relations of ecological interdependence and mutualism rather than dualism and anthropocentrism [5,12,13,15,16].
System transition as Three Horizons	<ul style="list-style-type: none"> This is the framing used to explain how an idealized, and deliberately stewarded, systemic change comes about [31]. The present system is viewed as the first horizon, and the desired future(s) as a more distant third horizon that emerges from strategic action in a second transitional horizon in the medium term [31]. In the second horizon, an explicit distinction is made between transformative innovations/activities and innovations/activities that are captured by the first horizon to extend its lifespan [31].

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emphasize the importance of re-localizing foodsheds, celebrating the uniqueness of places and regions, food sovereignty, regenerative and agroecological forms of farming, and elevating Indigenous knowledge [5,84]. Framing the future, transformed system, as being a regenerative one provides a powerful concept, aiming to drive ambition, imagination and transformation. We worked with this regenerative framing whilst allowing participants to co-create their own interpretation of what a future regenerative Yorkshire food system would look like.

System transition: Transformation also requires an explicit framing of how transformation is expected to come about. For this, we used the Three Horizons (3H) ontological framework of system transition [46] (Fig 2). This framework has been used to collaboratively explore alternative futures [31,85–89]. It views a transformed future as arising through an interplay of three horizons: the present first horizon that is declining as conditions around it change and it becomes increasingly less fit for purpose (H1); and a desired future third horizon (H3) that emerges from strategic action in a second transitional horizon (H2) in the medium term [31] (Fig 2). This framing helps focus explorations on how transformative innovations and activities ('H2+') can creatively disrupt H1, creating space for H3 to emerge, and on how to avoid reformist or conformist activities ('H2-') that extend the lifespan of H1 [31].

Together, the combination of explicit framings of a *food system*, that requires *transformation*, towards one that is *regenerative* and through a process of *system transition* provided a powerful ontological framework to examine how transformation can be supported.

Epistemology

Epistemological positions—how 'knowledge' and 'knowing' are understood—have a major bearing on the kinds of research methods applied, and thus the nature and form of the knowledge produced. In this research an iterative, action-oriented, and co-creative second-order

Table 6. Core philosophical and epistemological positions shaping the research approach and methods.

Philosophical or epistemological position	Explanation
Second-order science	Investigators viewed themselves as part of, and acting from within, the system they seek to understand and intervene in [73,90,91].
Eliciting multiple forms of knowledge	Three different forms of knowledge elicited: 1. evidence and experience from the past and present to understand challenges in the present; 2. normative imaginations about what kind of future system is desired; 3. creative ideation about how action can strategically support transformation [31,90].
Co-creation	Collective and engaged processes where sharing, reflection and learning could occur through an interactive process of dialogue and sense-making. This is in contrast to a more static and extractive process of data collection and analysis.
Adaptation & reflexivity	The research process adapts the method as new opportunities and insights emerge and as it receives feedback from participants [74]. This enhances possibilities for more creative outcomes and overcomes the limits of an assumption that a process for research can always be effectively predetermined [74].

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approach was applied (Table 6). This was deemed to be important for examining action needed to support large-scale food system transformation, where uncertainty and complexity prevail, there are multiple perspectives and ways the food system is being experienced, yet where information is needed to support urgent action and change.

Philosophically, second-order research is where investigators view themselves as part of, and acting from within, the system they seek to understand and intervene in. This is in contrast to a first-order approach, where researchers assume they can objectively stand from the outside, looking in [73,90,91]. Taking a second-order approach requires researchers and other investigators and actors to continually and critically reflect on how their personal involvement within the system influences observation and interpretation. It also widens scope for inclusion of much more diverse ways of knowing, recognizing in our case the value and importance of expertise and prospective, iterative and generative approaches where multiple actors can collectively explore future, envisioned food systems and co-create ideas about how systemic change might be achieved [31,74,90].

Epistemologically, three forms of knowledge and knowing were collected in the research: (1) experiential knowledge and evidence from the past and present about the challenges in the present (relating to H1); (2) normative imaginations about what kind of future system is desired (H3); and (3) creative ideation about how action can strategically support transformation [31,90] (H2). The first form represents the kinds of ‘truth’ we are more familiar with: truths based on evidence of what currently exists and has existed. The second is a different kind of truth that is often more prospective and subjective, but which is nonetheless a truth about what one desires to see in the world. The third is a more creative kind of knowledge, developed in many different ways but which focuses on bringing something tangible into being (in this case an idea about action). Our approach therefore went beyond the limits of traditional research that can be overly focused on provision of ‘evidence’ from the present or the past. Over-reliance on such knowledge can be like driving forward while looking through a rearview mirror [92]. To support transformation, other prospective, normative and creative forms of knowledge are also required [90].

The research was also co-creative. That is, it included involvement of many different actors in a structured process of dialogue. By working together, and by building on findings produced in different stages and workshops, individual and collective sense-making could be

enhanced, allowing effective strategic ideation to emerge [90]. This was in contrast to applying more static extractive processes that typically emerge from first-order scientific approaches [73] where much of the interpretation is conducted by external researchers. This limits opportunities for collective learning and sense-making needed for working with complex phenomena and where no single person will have a full understanding of the system being explored.

The co-creation was then supported by an adaptive method to the research [74] which allowed for a more iterative, reflexive and flexible approach that could respond to what was being discovered. At times, this allowed for the path of research to be altered to enhance its creative potential [74]. It also allowed the exploration and continued improvement of the process in response to feedback from the participants. While the overall structure of the process was predetermined and maintained, many specific steps were designed based on the results of previous steps. Examples of adaptation to the research process included introducing more narrative-based approaches to illustrate the system while phasing out use of complex system diagrams in workshops, and developing and applying a new Regenerative Lens [13] to help support the envisioning of an ambitious third horizon system.

Overall, the epistemological approach shaped the development and implementation of the methods, including design of workshops, how dialogue was convened, the questions used to stimulate ideation, the sequencing of different tasks, and analysis and interpretation.

Method

Overview

The research included an extensive process of eliciting knowledge, ideas and insights from a diverse range of experts across the food system using surveys and workshops. It included data collection over 14 months (October 2021 to December 2022), from a total of 114 researchers and food system experts. A total of 45.25 hours of workshops were conducted with around 1400 initial ideas generated (Fig 5).

Data collection was structured using the 3H process, focusing on understanding challenges in the present system, establishing future visions, and identifying activities needed to support system change. The process helped participants work with complexity and uncertainty, enabling them to constructively share their different perspectives [31,90].

The work included two main phases: (1) Exploring transformation using a series of surveys and workshops in each of three separate subsystems of the Yorkshire food system; and (2) integrating findings from the different subsystems (Fig 5).

The three subsystems included: agriculture (the subsystem most focused on 'production'); schools and early years (the 'consumption'-focused subsystem, hereafter abbreviated to 'schools'); and food economies (the 'distribution' subsystem). Together, while clearly not capturing every aspect, the three subsystems provided a holistic understanding of the food system, spanning production to consumption.

Activities of the three subsystems were coordinated by six FixOurFood researchers (the 'coordinating researchers'). These included professional facilitators, who designed and led surveys and workshops, and facilitated other participants in the process of analysis and interpretation.

Ethical approval for the research was granted by the University of York's Department of Environment and Geography Ethical Review Committee. Formal written consent was obtained from participants before they took part in the research.

Participants

The expert participants included a total of 85 wider stakeholders and 29 researchers, whose knowledge, ideas, and insights were elicited through surveys and workshops. This included, in

each subsystem, two to four FixOurFood researcher ‘subsystem leads’ who had enrolled a long-list of 20–30 ‘wider stakeholders’ who were experts working in, or studying, their Yorkshire subsystem. These wider stakeholders represented a broad range of organizations and different areas in Yorkshire (S1 Table), and had an in-depth understanding of diverse issues and experience of working with marginalized people. The researchers (e.g. subsystem leads), who also acted as participants, brought additional expertise relating to different aspects of the food system. All participants were tasked not just with providing their own perspective, but also with bringing in many other voices absent from the room.

Diverse participants—traditional researchers and wider stakeholders—were also involved in both the primary workshops to elicit ideas as well as in post-workshop meetings to interpret findings. As such, while there were distinct facilitators and overall process leads who managed and supported the research process (i.e. the coordinating researchers) who did not act as ‘participants’, there were also both ‘researchers’ and ‘stakeholders’ who acted as participants. Both of these participant researchers and wider stakeholders were equally considered to be ‘stakeholders’ and as having important expertise relevant to understanding transformation. Both kinds of participants provided essential understanding of nuances and interconnections of the food system in the process of analysis and interpretation.

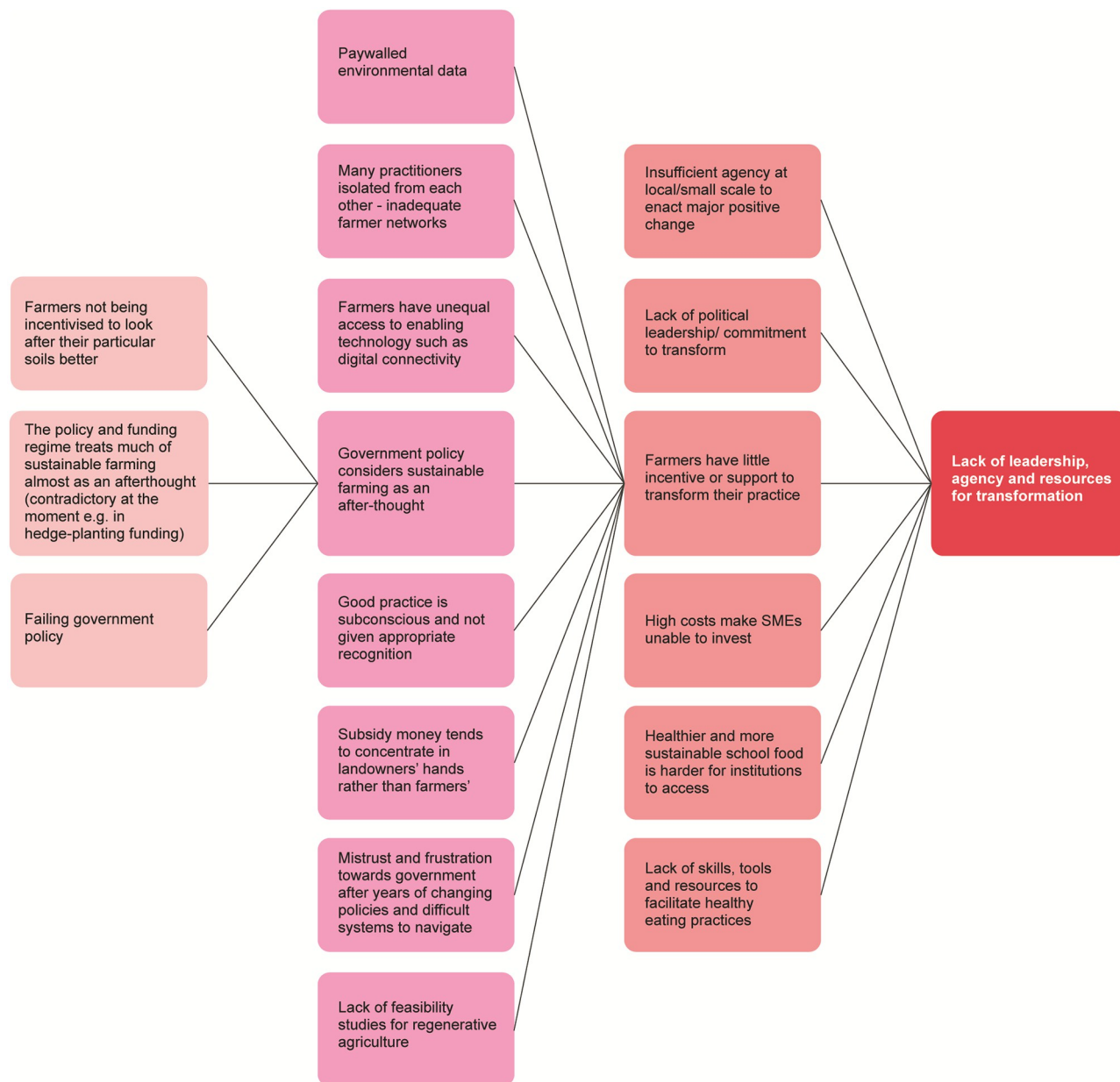
Phase 1: Work in individual subsystems

For each subsystem, a survey and three to four online workshops were held with participants on Zoom, each about a month apart. After an initial on-boarding workshop to introduce participants to each other, discuss the research context, and explain how the process would unfold, participants were sent a survey. This focused on the broad questions about challenges, envisioned systems and activities to support transformation, tailored to each subsystem, with open-ended answers. Survey responses were broken down into distinct points and transferred to post-it notes on the collaborative online whiteboard application Mural (<https://www.mural.co/>), keeping responses separate by subsystem. Post-its were inductively open-coded [93,94], and similar responses grouped (Fig 6). The initial themes were inductively coded to higher-level themes (Fig 6) and added to 3H maps on Mural. This work was facilitated by the overall process leads, with subsystem leads and selected wider stakeholders participating.

The three main workshops conducted for each subsystem involved:

- Workshop 1: This introduced and refined the 3H maps resulting from the survey responses, focusing on identifying challenges (H1) and elements in the envisioned systems (H3).
- Workshop 2 focused on understanding the contrast between the present and envisioned future, and identifying the H2+ actions needed to support the transformation. Between workshops 2 and 3, the subsystem leads and process leads drafted a ‘summary narrative’ of transformation: a brief bullet-point prose summary of H1, H2 and H3.
- Workshop 3 refined the summary narrative and identified ideas for next steps.
- In addition to these workshops, a separate in-person 3H workshop was held with secondary school pupils enrolled on FixOurFood’s Leaders for Change program. These are pupils from schools around Yorkshire, whose voices are integral to driving food transformation within their schools and communities, and for priority-setting around school food within FixOurFood.

Reports for each subsystem, including details of participants, questions, framings and results were created [95–97].



Raw survey responses

First-level themes

Second-level themes

Third-level themes

Fig 6. Example of the thematic coding process (Horizon 1). Raw survey responses were inductively grouped into first-level themes—i.e. each first-level theme is underpinned by one or more raw survey response (one example of this hierarchy, 'Government policy considers sustainable farming as an afterthought', is shown, and contains three raw survey responses). First-level themes were then inductively grouped into second-level themes—i.e. each second-level theme is underpinned by one or more first-level themes (one example of this hierarchy, 'Government policy considers sustainable farming as an afterthought', is shown). Figure originally created in Mural (<https://www.mural.co/>) and rendered by Dave Gledhill of 1790 Creative (<https://autografic.art/>).

<https://doi.org/10.1371/journal.pstr.0000134.g006>

Phase 2: Integrating results from different subsystems

Coordinating researchers created an integrated 3H map based on results from all subsystem workshops. The language and content of horizon themes were refined and sense-checked in an online workshop with the wider FixOurFood research team. An online workshop was then held with FixOurFood researchers to critically evaluate and push the ambition of the integrated H3 vision using a 'Regenerative Lens' [13] of key qualities associated with regenerative systems. This resulted in several modifications to the original H3 themes and some new themes added.

In a further online workshop, the main H2 themes were inductively clustered into five overarching priority action domains by FixOurFood researchers, with critical reflection on their potential for supporting systemic change and in relation to where there was considered to be an existing momentum for change. The clustering process brought together themes that supported or reinforced other themes, not just on whether they were similar in their content.

An in-person, two-day professionally facilitated workshop, attended by FixOurFood researchers and wider stakeholders, was then held. Here the five action domains were presented and participants explored: a) why each domain was considered to have transformative potential, and b) what enabling conditions were needed around each area to support them. H3 themes (based on results of applying the Regenerative Lens) were also inductively clustered into six 'meta-themes', with clustering being based on which theme supported or reinforced another. H1 was also inductively grouped into seven meta-themes of similar content (Fig 6). The narratives around the five H2 action domains were refined based on Otter.ai-transcribed audio transcripts of workshop discussions.

To deepen understanding about how the five action domains would work together in a mutualistic way, participants were led through an 'offers and requests' exercise during the two-day workshop. Participants were divided into five teams, one per action domain. Each team identified what its associated action domain could offer, and would require from, the four other domains to support transformation. The offers are reported in this paper (Fig 4). The mutualistic support between the action domains was subsequently treated as its own, sixth, action domain.

Although the process of 'distilling' information throughout the subsystem and integration work inevitably lost some nuance, 3H aims to cohere and distill complexity into something meaningful and motivating that broadly guides action and stimulates critical reflexivity, rather than capture every detail, which would quickly become overwhelming [31,90]. Throughout the 3H process, if tensions or contradictions arose between participants' offerings, these were noted by the facilitators and retained in the final results if there was no objection from participants, rather than fully resolved.

Final authorship of the co-created research

FixOurFood researchers and wider stakeholders contributed to final refinement and sense-checking of the results in drafts of this article. As with other co-created research, it can be difficult to discern the origin of ideas or precise input of those involved. Separation between researcher, author, or participant is not so easy to discern and, in such a process of co-creation, all involved have legitimate claims to the production of knowledge. As such, participants were invited, through an opt-in process, to be authors on this manuscript. Author contributions were categorized according to the CrediT terminology [98].

Supporting information

S1 Table. Full list of organizations represented by participants in this research.
(DOCX)

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We are exceptionally grateful for the input from all of FixOurFood's stakeholders in shaping this work (see [S1 Table](#) for the list of contributing organizations). We wish to dedicate this paper to the memory of the late Professor Steven Banwart, who was pivotal to this work and the wider FixOurFood project. If you found this paper useful at your institution/organization, please let us know, as we are interested in impact beyond academic citations.

Author Contributions

Conceptualization: Sam J. Buckton, Ioan Fazey, Bob Doherty, Maria Bryant, Steven A. Banwart, Esther Carmen, Ian Kendrick, Bill Sharpe, Eugyen Suzanne Om.

Data curation: Sam J. Buckton, Esther Carmen, Annie Connolly, Ian Kendrick, Ruth N. Wade, Anthonia James, Belinda Morris, Sophie Stewart, Ulrike Ehgartner.

Formal analysis: Sam J. Buckton, Ioan Fazey, Bob Doherty, Maria Bryant, Steven A. Banwart, Esther Carmen, Annie Connolly, Katherine Denby, Ian Kendrick, Bill Sharpe, Ruth N. Wade, Peter Ball, Sarah Bridle, Grace Gardner, Anthonia James, Belinda Morris, Sophie Stewart, Myles Bremner, Juan Pablo Cordero, Henk Geertsema, Nicola Nixon, Eugyen Suzanne Om, Maddie Sinclair, Jan Thornton, Christopher Yap, Dave Arnott, Ben Fletcher, Jack Garry, Rebecca Lait, Adrian Lovett, Melanie Reed.

Funding acquisition: Ioan Fazey, Bob Doherty, Maria Bryant, Steven A. Banwart, Katherine Denby, Peter Ball, Sarah Bridle, Pippa J. Chapman, Michelle Cain, Corinna Hawkes, Kate E. Pickett, Tim Frenneux.

Investigation: Sam J. Buckton, Ioan Fazey, Bob Doherty, Maria Bryant, Steven A. Banwart, Esther Carmen, Annie Connolly, Katherine Denby, Ian Kendrick, Bill Sharpe, Ruth N. Wade, Peter Ball, Sarah Bridle, Grace Gardner, Anthonia James, Belinda Morris, Sophie Stewart, Myles Bremner, Pippa J. Chapman, Juan Pablo Cordero, Henk Geertsema, Nicola Nixon, Eugyen Suzanne Om, Maddie Sinclair, Jan Thornton, Christopher Yap, Dave Arnott, Michelle Cain, Ulrike Ehgartner, Ben Fletcher, Jack Garry, Alana Kluczkowski, Rebecca Lait, Adrian Lovett, Melanie Reed, Nathan Atkinson, Fiona Black, Mark Blakeston, Wendy Burton, Margaret Anne Defeyter, Naomi Duncan, Glynn Eastwood, Ruth Everson, Angelina Frankowska, Sian Goodwin, Harry Holden, Helen Ingle, Allison Kane, Christine Parry, Victoria Robertshaw, Tom Scrope, Phillippa Sellstrom, Stephanie Slater, Kim Smith, Ruth Stacey, Gary Stott, Alastair Trickett, Jessica Wilson.

Methodology: Sam J. Buckton, Ioan Fazey, Bob Doherty, Maria Bryant, Steven A. Banwart, Esther Carmen, Annie Connolly, Ian Kendrick, Bill Sharpe, Ruth N. Wade, Grace Gardner, Maddie Sinclair.

Project administration: Anthonia James, Belinda Morris, Sophie Stewart.

Supervision: Ioan Fazey, Bob Doherty, Maria Bryant, Steven A. Banwart, Katherine Denby.

Visualization: Sam J. Buckton, Ioan Fazey, Juan Pablo Cordero, Dave Gledhill.

Writing – original draft: Sam J. Buckton.

Writing – review & editing: Sam J. Buckton, Ioan Fazey, Bob Doherty, Maria Bryant, Annie Connolly, Katherine Denby, Bill Sharpe, Ruth N. Wade, Peter Ball, Sarah Bridle, Grace Gardner, Myles Bremner, Pippa J. Chapman, Henk Geertsema, Nicola Nixon, Jan Thornton, Christopher Yap, Corinna Hawkes, Alana Kluczkowski, Kate E. Pickett, Rebecca Newman.

References

1. Webb P, Benton TG, Beddington J, Flynn D, Kelly NM, Thomas SM. The urgency of food system transformation is now irrefutable. *Nat Food*. 2020; 1: 584–585. <https://doi.org/10.1038/s43016-020-00161-0> PMID: 37128102
2. Benton TG, Bieg C, Harwatt H, Pudasaini R, Wellesley L. Food system impacts on biodiversity loss: Three levers for food system transformation in support of nature. London: Chatham House; 2021. https://www.chathamhouse.org/sites/default/files/2021-02/2021-02-03-food-system-biodiversity-loss-benton-et-al_0.pdf
3. Brück T, d'Errico M. Food security and violent conflict: Introduction to the special issue. *World Dev*. 2019; 117: 167–171. <https://doi.org/10.1016/j.worlddev.2019.01.007>
4. Tubiello FN, Karl K, Flammini A, Gütschow J, Obli-Laryea G, Conchedda G, et al. Pre- and post-production processes increasingly dominate greenhouse gas emissions from agri-food systems. *Earth Syst Sci Data*. 2022; 14: 1795–1809. <https://doi.org/10.5194/essd-14-1795-2022>
5. Duncan J, Carolan M, Wiskerke JSC, editors. *Routledge Handbook of Sustainable and Regenerative Food Systems*. 1st Edition. Abingdon-on-Thames: Routledge; 2020.
6. Herren HR, Haerlin B, IAASTD+10 Advisory Group. Transformation of our food systems: The making of a paradigm shift. Berlin & Zurich: Zukunftsstiftung Landwirtschaft & Biovision; 2020. <https://www.globalagriculture.org/fileadmin/files/weltagrabericht/IAASTD-Buch/PDFBuch/BuchWebTransformationFoodSystems.pdf>
7. O'Brien K, Sygna L. Responding to climate change: The three spheres of transformation. *Proceedings of Transformation in a Changing Climate*. 2013. pp. 16–23. https://www.researchgate.net/publication/309384186_Responding_to_climate_change_The_three_spheres_of_transformation
8. Davelaar D. Transformation for sustainability: a deep leverage points approach. *Sustain Sci*. 2021; 16: 727–747. <https://doi.org/10.1007/s11625-020-00872-0>
9. Feola G. Societal transformation in response to global environmental change: A review of emerging concepts. *Ambio*. 2015; 44: 376–390. <https://doi.org/10.1007/s13280-014-0582-z> PMID: 25431335
10. Dahlberg KA. A transition from agriculture to regenerative food systems. *Futures*. 1994; 26: 170–179. [https://doi.org/10.1016/0016-3287\(94\)90106-6](https://doi.org/10.1016/0016-3287(94)90106-6)
11. Loring PA. Regenerative food systems and the conservation of change. *Agric Human Values*. 2022; 39: 701–713. <https://doi.org/10.1007/s10460-021-10282-2> PMID: 34776604
12. McGreevy SR, Rupprecht CDD, Niles D, Wiek A, Carolan M, Kallis G, et al. Sustainable agrifood systems for a post-growth world. *Nat Sustain*. 2022; 1–7. <https://doi.org/10.1038/s41893-022-00933-5>
13. Buckton SJ, Fazey I, Sharpe B, Om S, Doherty B, Denby K, et al. The Regenerative Lens: A conceptual framework for regenerative social-ecological systems. *One Earth*. 2023; 6: 824–842. <https://doi.org/10.1016/j.oneear.2023.06.006>
14. Benyus JM. *Biomimicry: Innovation Inspired by Nature*. 2nd ed. Boston: Mariner Books; 2002. <https://www.amazon.co.uk/Biomimicry-Innovation-Inspired-Janine-Benyus/dp/0060533226>.
15. Camrass K. Regenerative futures. *Foresight*. 2020; 22: 401–415. <https://doi.org/10.1108/FS-08-2019-0079>
16. Wahl DC. *Designing Regenerative Cultures*. Bridport: Triarchy Press; 2016.
17. Newton P, Civita N, Frankel-Goldwater L, Bartel K, Johns C. What Is Regenerative Agriculture? A Review of Scholar and Practitioner Definitions Based on Processes and Outcomes. *Front Sustain Food Syst*. 2020; 4. <https://doi.org/10.3389/fsufs.2020.577723>
18. Lal R. Regenerative agriculture for food and climate. *J Soil Water Conserv*. 2020; jswc.2020.0620A. <https://doi.org/10.2489/jswc.2020.0620A>
19. Bless A, Davila F, Plant R. A genealogy of sustainable agriculture narratives: implications for the transformative potential of regenerative agriculture. *Agric Human Values*. 2023; 40: 1379–1397. <https://doi.org/10.1007/s10460-023-10444-4>

20. Titttonell P, El Mujtar V, Felix G, Kebede Y, Laborda L, Luján Soto R, et al. Regenerative agriculture—agroecology without politics? *Front Sustain Food Syst.* 2022; 6. <https://doi.org/10.3389/fsufs.2022.844261>
21. Doherty B, Bryant M, Denby K, Fazey I, Bridle S, Hawkes C, et al. Transformations to regenerative food systems—An outline of the FixOurFood project. *Nutr Bull.* 2022; 47: 106–114. <https://doi.org/10.1111/nbu.12536> PMID: 36045085
22. Fazey I, Colvin J. Transformation: An introductory guide to fundamental change for researchers and change makers in a world of crises—A Report for the Transforming UK Food Systems SPF Programme. York & Stroud: University of York & Emerald Network Ltd; 2023 Jun. <https://ukfoodsystems.ukri.org/transformation-a-guide-to-fundamental-change-in-a-world-of-crisis/>.
23. Treuherz S, Yap C, Rowson S. ShefFood's local food action plan for Sheffield. Sheffield & York/London: ShefFood and FixOurFood; 2023. <https://sheffood.org.uk/wp-content/uploads/2023/06/sheffield-local-food-action-plan-2023-links.pdf>.
24. City of Bradford Metropolitan District Council. Bradford District Good Food Strategy 2023. Bradford: City of Bradford Metropolitan District Council; 2023. <https://www.bradford.gov.uk/health/living-well/bradford-district-good-food-strategy/#:~:text=Our%20Vision%20is%3A%20%22To%20put,and%20strengthens%20our%20local%20economy%22.>
25. Route A. Hull Food Strategy—NEW survey—complete and win. In: Hull Food Partnership [Internet]. 20 Jan 2022 [cited 25 Aug 2023]. <https://hullfoodpartnership.org.uk/hull-food-strategy-new-survey-complete-and-win/>.
26. Foodwise Leeds. Leeds Food Action Plan. In: Foodwise Leeds [Internet]. [cited 25 Aug 2023]. <https://foodwiseleeds.org/about/leeds-food-action-plan/>.
27. Wall S. Farmer Scientist Network. In: Yorkshire Agricultural Society [Internet]. 29 Jan 2019 [cited 24 Jul 2024]. <https://yas.co.uk/fsn/>.
28. Grow Yorkshire. In: York and North Yorkshire Combined Authority [Internet]. 21 Dec 2023 [cited 5 Jul 2024]. <https://yorknorthyorks-ca.gov.uk/growing-our-economy/economic-framework/green-economy/grow-yorkshire/>.
29. Deliciously Yorkshire. In: Deliciously Yorkshire [Internet]. 16 Jun 2014 [cited 5 Jul 2024]. <https://deliciouslyyorkshire.co.uk/>.
30. The University of Sheffield. New map shows where millions of UK residents struggle to access food. In: The University of Sheffield [Internet]. 22 Jul 2021 [cited 19 Jun 2023]. <https://www.sheffield.ac.uk/news/new-map-shows-where-millions-uk-residents-struggle-access-food>.
31. Sharpe B, Hodgson A, Leicester G, Lyon A, Fazey I. Three horizons: a pathways practice for transformation. *Ecol Soc.* 2016; 21: 47. <https://doi.org/10.5751/ES-08388-210247>
32. Cordero JP, Donkers K, Harrison I, Bridle SL, Frankowska A, Cain M, et al. AgriFoodPy: a package for modelling food systems. *J Open Source Softw.* 2024; 9: 6305. <https://doi.org/10.21105/joss.06305>
33. Graver A. York and North Yorkshire Covid Recovery Insight Project Food Insecurity Research: The efficacy of different food access models. York: Skyblue Research Limited; 2023. <https://www.skyblue.org.uk/foodinsecurity/main-report/>.
34. Malik X, Smith L, Stewart I, Burnett N. Food waste in the UK (Commons Library Research Briefing). London: The House of Commons Library; 2024 Apr. <https://researchbriefings.files.parliament.uk/documents/CBP-7552/CBP-7552.pdf>.
35. Food Circle York CIC. In: Food Circle York CIC [Internet]. [cited 15 Dec 2023]. <https://www.foodcircleyork.co.uk/>.
36. Doherty B, Haugh H, Lyon F. Social enterprises as hybrid organizations: A review and research agenda. *Int J Manag Rev.* 2014; 16: 417–436. <https://doi.org/10.1111/ijmr.12028>
37. Wall S. Future Farmers—A group for farmers, vets and industry supporters. In: Yorkshire Agricultural Society [Internet]. 29 Jan 2019 [cited 15 Dec 2023]. <https://yas.co.uk/futurefarmers/>.
38. TastEd. Taste Education: Food Education Like You've Never TastEd Before. In: TastEd [Internet]. 8 Jul 2020 [cited 24 Aug 2023]. <https://www.tasteeducation.com/>.
39. Rethink Food. In: Rethink Food [Internet]. [cited 24 Aug 2023]. <https://www.rethinkfood.org/>.
40. Farmer Time. In: Farmer Time [Internet]. [cited 2 Aug 2024]. <https://www.farmertime.uk/>.
41. Open Farm Sunday. In: Open Farm Sunday [Internet]. [cited 2 Aug 2024]. <https://farmsunday.org/>.
42. Soil Benchmark. In: Soil Benchmark [Internet]. [cited 24 Aug 2023]. <https://www.soilbenchmark.com/>.
43. Soilmentor. In: Vidacycle [Internet]. [cited 2 Aug 2024]. <https://soils.vidacycle.com/>
44. Take a Bite Out Of Climate Change. In: Take a Bite Out Of Climate Change [Internet]. [cited 24 Aug 2023]. <https://www.takeabitecc.org/>.

45. Waddock S. Catalyzing purposeful transformation: The emergence of transformation catalysts. *Bus Soc Rev.* 2022; 127: 167–170. <https://doi.org/10.1111/basr.12263>
46. Fazey I, Leicester G. Archetypes of system transition and transformation: Six lessons for stewarding change. *Energy Res Soc Sci.* 2022; 91: 102646. <https://doi.org/10.1016/j.erss.2022.102646>
47. Hasnain S, Ingram J, Zurek M. Mapping the UK Food System—a report for the UKRI Transforming UK Food Systems Programme. Oxford: Environmental Change Institute, University of Oxford; 2020. <https://www.foodsecurity.ac.uk/wp-content/uploads/2009/10/Mapping-the-UK-food-system-digital.pdf>.
48. Food, Farming & Countryside Commission. Our Future in the Land. London: RSA; 2019. <https://cdn2.assets-servd.host/ffcc-uk/production/assets/downloads/FFCC-Our-Future-in-the-Land.pdf>.
49. Clapp J. Concentration and crises: exploring the deep roots of vulnerability in the global industrial food system. *J Peasant Stud.* 2023; 50: 1–25. <https://doi.org/10.1080/03066150.2022.2129013>
50. FAO, IFAD, UNICEF, WFP, WHO. The State of Food Security and Nutrition in the World 2023. Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum. Rome: FAO; 2023.
51. Kopittke PM, Menzies NW, Wang P, McKenna BA, Lombi E. Soil and the intensification of agriculture for global food security. *Environ Int.* 2019; 132: 105078. <https://doi.org/10.1016/j.envint.2019.105078> PMID: 31400601
52. Waddock S, Waddell S. Transformation Catalysts: Weaving Transformational Change for a Flourishing World for All. *Cadmus.* 2021; 4: 165–182. Available: <http://www.cadmusjournal.org/node/876>.
53. van den Berg RD, Magro C, Adrien M-H, editors. Transformational Evaluation for the Global Crises of Our Times. Exeter: IDEAS; 2021. <https://ideas-global.org/wp-content/uploads/2021/07/2021-IDEAS-book-Transformational-Evaluation.pdf>.
54. Norton LR, Bruce A, Chapman PJ, Lamprinoupolou C, Rothwell SA, Smith LG. Identifying levers for change in UK grazing livestock systems. *Front Sustain Food Syst.* 2024; 8: 1366204. <https://doi.org/10.3389/fsufs.2024.1366204>
55. Stewart S. FixOurFood Commission. In: FixOurFood [Internet]. 1 Feb 2024 [cited 24 Jul 2024]. <https://fixourfood.org/commission/>.
56. Faculty of Biological Sciences. What can soil teach us about sustainability? In: University of Leeds [Internet]. 12 May 2023 [cited 24 Jul 2024]. <https://biologicalsciences.leeds.ac.uk/biological-sciences/news/article/431/what-can-soil-teach-us-about-sustainability>.
57. Darley K. Have your say on the future of food in North Yorkshire. *Gazette & Herald.* 1 Mar 2024. <https://www.gazetteherald.co.uk/news/24154442.say-future-food-north-yorkshire/>. Accessed 3 Jul 2024.
58. Energy & Climate Intelligence Unit. Climate impacts on UK food imports—Spotlight on: climate-vulnerable countries. London: Energy & Climate Intelligence Unit; 2023 Nov. <https://ca1-eci.edcdn.com/food-vulnerable-Nov-2023.pdf?v=1701692173>.
59. El Bilali H, Ben Hassen T. Disrupted harvests: how Ukraine–Russia war influences global food systems—a systematic review. *Policy Stud.* 2024; 45: 310–335. <https://doi.org/10.1080/01442872.2024.2329587>
60. Cole J, Petrikova I. UK and global food security in the era of “permacrisis.” *RUSI J.* 2024; 169: 10–20. <https://doi.org/10.1080/03071847.2024.2343726>
61. Slaughter RA. Futures beyond dystopia. *Futures.* 1998; 30: 993–1002. [https://doi.org/10.1016/S0016-3287\(98\)00101-3](https://doi.org/10.1016/S0016-3287(98)00101-3)
62. Gronchi I, Jousilahti J, Leppänen J, Lancaster N, Nuutinen J, Saramäki R, et al. Turning the tide: Landscape analysis of an emergent economic movement in Europe. Helsinki: Demos Helsinki; 2022. <https://demoshelsinki.fi/wp-content/uploads/2022/01/Turning-the-tide-v.022022.pdf>.
63. Joseph Rowntree Foundation. Emerging futures. In: JRF [Internet]. 1 Feb 2022 [cited 25 Aug 2023]. <https://www.jrf.org.uk/society/emerging-futures>.
64. Vallone S, Lambin EF. Public policies and vested interests preserve the animal farming status quo at the expense of animal product analogs. *One Earth.* 2023; 6: 1213–1226. <https://doi.org/10.1016/j.oneear.2023.07.013>
65. Rust NA, Ridding L, Ward C, Clark B, Kehoe L, Dora M, et al. How to transition to reduced-meat diets that benefit people and the planet. *Sci Total Environ.* 2020; 718: 137208. <https://doi.org/10.1016/j.scitotenv.2020.137208> PMID: 32088475
66. Scarborough P, Clark M, Cobiaci L, Papier K, Knuppel A, Lynch J, et al. Vegans, vegetarians, fish-eaters and meat-eaters in the UK show discrepant environmental impacts. *Nat Food.* 2023; 4: 565–574. <https://doi.org/10.1038/s43016-023-00795-w> PMID: 37474804
67. Leroy F, Abraini F, Beal T, Dominguez-Salas P, Gregorini P, Manzano P, et al. Animal board invited review: Animal source foods in healthy, sustainable, and ethical diets—An argument against drastic

- limitation of livestock in the food system. *Animal*. 2022; 16: 100457. <https://doi.org/10.1016/j.animal.2022.100457> PMID: 35158307
68. Cusworth G, Lorimer J, Brice J, Garnett T. Green rebranding: Regenerative agriculture, future-pasts, and the naturalisation of livestock. *Trans Inst Br Geogr*. 2022. <https://doi.org/10.1111/tran.12555> PMID: 36618006
 69. Brown P, Cardenas L, Choudrie S, Del Vento S, Karagianni E, MacCarthy J, et al. UK Greenhouse Gas Inventory, 1990 to 2020. London: Department for Business, Energy & Industrial Strategy; 2022. https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2206220830_ukghgi-90-20_Main_Issue1.pdf.
 70. Samanta P, Horn H, Saravia F. Impact of livestock farming on nitrogen pollution and the corresponding energy demand for zero liquid discharge. *Water*. 2022; 14: 1278. <https://doi.org/10.3390/w14081278>
 71. De Groeve B, Bleys B, Hudders L. Ideological resistance to veg*n advocacy: An identity-based motivational account. *Front Psychol*. 2022; 13: 996250. <https://doi.org/10.3389/fpsyg.2022.996250> PMID: 36533047
 72. van Mierlo B, Arkesteijn M, Leeuwis C. Enhancing the Reflexivity of System Innovation Projects With System Analyses. *Am J Eval*. 2010; 31: 143–161. <https://doi.org/10.1177/1098214010366046>
 73. Fazey I, Schöpke N, Caniglia G, Patterson J, Hultman J, van Mierlo B, et al. Ten essentials for action-oriented and second order energy transitions, transformations and climate change research. *Energy Res Soc Sci*. 2018; 40: 54–70. <https://doi.org/10.1016/j.erss.2017.11.026>
 74. van Assche K, Beunen R, Duineveld M, Gruezmacher M. Adaptive methodology. Topic, theory, method and data in ongoing conversation. *Int J Soc Res Methodol*. 2023; 26: 35–49. <https://doi.org/10.1080/13645579.2021.1964858>
 75. López Cifuentes M, Penker M, Kaufmann L, Wittmann F, Fiala V, Gugerell C, et al. Diverse types of knowledge on a plate: a multi-perspective and multi-method approach for the transformation of urban food systems towards sustainable diets. *Sustain Sci*. 2023; 18: 1613–1630. <https://doi.org/10.1007/s11625-022-01287-9> PMID: 36789006
 76. Future Stewards, Leaders' Quest, High-Level Climate Action Champions for UN COP. 10 tools for systems change to a zero carbon world. Future Stewards; 2021. <https://futurestewards.com/wp-content/uploads/2021/12/10-tools-for-systems-change-to-a-zero-carbon-world.pdf>.
 77. Holmes AGD. Researcher Positionality—A Consideration of Its Influence and Place in Qualitative Research—A New Researcher Guide. *Shanlax Int J Educ*. 2020; 8: 1–10. <https://doi.org/10.34293/education.v8i4.3232>
 78. Sellberg MM, Cockburn J, Holden PB, Lam DPM. Towards a caring transdisciplinary research practice: navigating science, society and self. *Ecosyst People*. 2021; 17: 292–305. <https://doi.org/10.1080/26395916.2021.1931452>
 79. Dahlberg KA. Regenerative food systems. In: Hudson RJ, editor. *Management of Agricultural, Forestry, Fisheries and Rural Enterprise*. Oxford: UNESCO, EOLSS Publishers; 2006. pp. 172–189.
 80. Duncan J, Carolan MS, Wiskerke JSC. *Routledge Handbook of Sustainable and Regenerative Food Systems*. Routledge, Taylor & Francis Group; 2020.
 81. Bhunnoo R, Poppy GM. A national approach for transformation of the UK food system. *Nat Food*. 2020; 1: 6–8. <https://doi.org/10.1038/s43016-019-0019-8>
 82. Ingram J, Thornton P. What does transforming food systems actually mean? *Nat Food*. 2022; 3: 881–882. <https://doi.org/10.1038/s43016-022-00620-w> PMID: 37118208
 83. Reed B. Shifting from “sustainability” to regeneration. *Build Res Inf*. 2007; 35: 674–680. <https://doi.org/10.1080/09613210701475753>
 84. Gibbons LV. Regenerative—The New Sustainable? *Sustain Sci Pract Policy*. 2020; 12: 5483. <https://doi.org/10.3390/su12135483>
 85. Stewart I, Capello MA, Mouri H, Mhopjeni K, Raji M. Three Horizons for Future Geoscience. *Earth Sci Syst Soc*. 2023; 3. <https://doi.org/10.3389/esss.2023.10079>
 86. Collste D, Aguiar APD, Harmáčková ZV, Galafassi D, Pereira LM, Selomane O, et al. Participatory pathways to the Sustainable Development Goals: inviting divergent perspectives through a cross-scale systems approach. *Environ Res Commun*. 2023; 5: 055014. <https://doi.org/10.1088/2515-7620/acce25>
 87. Colloff MJ, Lavorel S, van Kerkhoff LE, Wyborn CA, Fazey I, Gorddard R, et al. Transforming conservation science and practice for a postnormal world. *Conserv Biol*. 2017; 31: 1008–1017. <https://doi.org/10.1111/cobi.12912> PMID: 28225163
 88. Adams D. The Future of Sport and Recreation in New Zealand. *J Futures Stud*. 2022; 8. Available: <https://jfsdigital.org/articles-and-essays/2023-2/vol-28-no-1-september-2023/the-future-of-sport-and-recreation-in-new-zealand/>.

89. Harmáčková ZV, Blättler L, Aguiar APD, Daněk J, Krpec P, Vačkářová D. Linking multiple values of nature with future impacts: value-based participatory scenario development for sustainable landscape governance. *Sustain Sci*. 2022; 17: 849–864. <https://doi.org/10.1007/s11625-021-00953-8>
90. Fazey I, Schäpke N, Caniglia G, Hodgson A, Kendrick I, Lyon C, et al. Transforming knowledge systems for life on Earth: Visions of future systems and how to get there. *Energy Res Soc Sci*. 2020; 70: 101724. <https://doi.org/10.1016/j.erss.2020.101724>
91. Umpleby SA. Second-Order Cybernetics as a Fundamental Revolution in Science. *Constr Found*. 2016; 11: 455–465. Available: <http://constructivist.info/11/3/455.umpleby.pdf>.
92. Hodgson A. Towards an ontology of the present moment. *Horizon*. 2013; 21: 24–38. <https://doi.org/10.1108/10748121311297049>
93. Corbin JM, Strauss A. Grounded theory research: Procedures, canons, and evaluative criteria. *Qual Sociol*. 1990; 13: 3–21. <https://doi.org/10.1007/BF00988593>
94. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol*. 2006; 3: 77–101. <https://doi.org/10.1191/1478088706qp063oa>
95. FixOurFood. Transforming to a regenerative farming system in Yorkshire: Summary report of the co-creative Three Horizons process. University of York, York: FixOurFood; 2022. <https://fixourfood.org/wp-content/uploads/2022/12/Transforming-to-a-regenerative-farming-system-in-Yorkshire.pdf>.
96. FixOurFood. Transformation of Yorkshire's food economies: Summary report of the co-creative Three Horizons process. University of York, York: FixOurFood; 2022. <https://fixourfood.org/wp-content/uploads/2022/06/Transformation-of-Yorkshires-Hybrid-Food-Economies-report.pdf>.
97. FixOurFood. Transforming food culture in Yorkshire's schools and early years settings: Summary report of the co-creative Three Horizons process. University of York, York: FixOurFood; 2022. <https://fixourfood.org/wp-content/uploads/2022/11/Transforming-Yorkshires-school-food-culture.pdf>.
98. Brand A, Allen L, Altman M, Hlava M, Scott J. Beyond authorship: attribution, contribution, collaboration, and credit. *Learn Publ*. 2015; 28: 151–155. <https://doi.org/10.1087/20150211>



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Transformative action towards regenerative food systems: a large-scale case study

Buckton, Sam J.; Fazey, Ioan; Doherty, Bob; Bryant, Maria; Banwart, Steven A.

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