Exploring Boundaries in Food Systems Research

Implications for Projects on UK Food Security

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Please cite this Report as:

Helfgott, A & Midgley, G. 2020. Exploring Boundaries in Food Systems Research: Implications for Projects on UK Food Security. 40p. The Global Food Security Programme, Swindon, UK.

Executive Summary

This report describes the Global Food Security (GFS) Boundaries Project, which represents the first systematic attempt to apply critical systems thinking and practice to a food systems research programme (as opposed to a single food system project). The focus was the *Global Food Security – Resilience of the UK Food System in a Global Context* (GFS-FRS) Research Programme, made up of 13 projects looking at different aspects of the UK food system.

The GFS Boundaries Project conducted reflection on boundary judgements within and across the 13 projects in order to support the systemic practice in those projects; situate them in relation to one another; and provide a means to make sense of the various conclusions and recommendations for action generated through the programme. The boundary reflection methodology used in the project drew on both Critical Systems Heuristics (CSH) (Ulrich 1983, 1987) and Systemic Intervention (Midgley 2000a). The findings from the research, which are being reported before the 13 projects have all concluded, can be summarised as follows:

Each of the 13 projects takes a distinct lens on the resilience of the UK food system. Though there are overlapping elements, each has distinct purposes, operates with different scopes, scales and resolutions, and each makes different boundary judgements. Accordingly, the various projects are generating different forms of knowledge, conclusions and recommendations for action, conditioned by their contrasting boundary judgments. There are synergies and tensions between the recommendations for action coming out of some of the projects.

The seemingly contradictory results from the different projects actually highlight where tensions exist across sectors, scales and levels within the broader system. Once they are identified, these tensions can be consciously managed. It turns out that applying multiple, contrasting lenses to 'the UK food system' provides valuable insights, precisely concerning where tensions and synergies exist.

In terms of food system activities and outcomes, there is a focus on production across the projects, though most projects include some other food system activities, and all consider other social and environmental outcomes of the food system. No projects include all food system activities. Few projects consider nutritional security. The majority are commodity focused. Only one project focuses on post farm-gate food waste, but this is just looking at phosphorus in waste water.

The projects also differ greatly in their specification of 'outcomes'. Some projects define socio-economic outcomes in terms of the economic viability of farms; others in terms of 'thriving communities' or 'better food choices'. Some projects see food security in terms of maintaining tonnage of supply, while others look at it as maintaining the ecosystem services that underpin on-going food production into the future. The concept of 'outcomes' of the system in all of the projects is relative to their choice of purposes and values, which in turn directs the setting of a boundary around what is seen as being in the food system (and consequently what comes to be excluded or marginalised).

There is also a distinction between projects that focus on maintaining or improving an existing system architecture and its activities, and projects that seek to maintain and improve outcomes, which may be emergent from multiple systems. For example, one project focuses on maintaining and improving the existing fresh fruit and vegetable supply system, whereas another is focused on maintaining pollination services as an outcome of food system activities more broadly.

A key conclusion is that there is not one single food system (or even a single system comprised of interacting sub-systems), but rather *multiple ways of looking*, with a systems-thinking lens, at what is

going on with food. Whichever 'whole' (and constitutive parts) we attend to, whether it is a relatively large one or not, we are potentially marginalizing or excluding certain people or concerns. This is because there is no such thing as a 'whole' that includes everything within it. It is therefore imperative that we attend, not simply to the good of a single whole, but rather to the good of *multiple nested and overlapping wholes*, visible to different stakeholders, and to the richness of detail and the value conflicts this inevitably reveals. Boundary reflection is a process that can help food system researchers pay attention to just these things. It can never be comprehensive, but it can help researchers do better than just take a single boundary for granted. It can therefore help researchers anticipate possible unwanted economic, social or environmental side-effects of their recommendations for change.

1 Introduction

1.1 Context

The research reported here has been undertaken under the auspices of the Global Food Security – Food System Resilience (GFS-FSR) Research Programme. GFS-FSR is coordinated by a team within the Food Systems Group, Environmental Change Institute, University of Oxford. The Oxford coordination team supports the projects in their individual objectives and works with them to integrate research activities and findings into the programme.

GFS-FSR is made up of 13 distinct research projects, which range in purpose, framing and approach. The way the projects relate to each other was not designed: each project was selected based on its individual merits rather than in terms of how they fit together. As a result, although they all say something about food, the projects do not collectively constitute comprehensiveness or even coherence. Each project represents a particular lens on UK food system resilience from a particular framing, shaped by a particular set of values linked to particular purposes.

Each individual, interdisciplinary project is itself composed of teams of diverse researchers from different institutions. Within projects, there can also be differences of opinion with regard to the purpose, framing and approaches used. In cases where projects have come together rapidly, or certain researchers might not know each other very well, differences of opinion regarding purpose, framing and approach can continue to surface and evolve throughout the project.

1.2 Motivation

The motivation for this piece of research arose from the dual aims of the Oxford coordination team, in the context described above, where potentially conflicting recommendations can arise from differences both across and within the 13 distinct research projects.

Systemic boundary critique – a process of conscious reflection on choices made regarding purpose, framing and approach (Midgley 2000a), both within and across projects, was proposed as a means to support the projects in their individual objectives, and to potentially provide a common language of boundaries and values for working to integrate findings across the programme.

Within individual projects, reflection on boundary judgements is a form of capacity development with respect to systems thinking. It also supports sense-making of information and knowledge gained from various sources, including stakeholders using different frames of reference; helps to identify potential biases and blind-spots; helps deal with value conflicts arising within teams regarding the inclusion or exclusion of particular focal issues; and helps to surface unexpected insights.

Across projects, the process of systemic boundary critique helps to identify interactions across the phenomena the projects address; and identify when recommendations are made by one project that, if implemented, might positively or negatively affect the outcomes of a different project. Accordingly, such reflection supports the development of a coherent set of programme-wide recommendations for improving resilience of the UK food system, taking account of the synergies and trade-offs identified.

Note that, from a systems-thinking perspective, the tensions both within and across programmes are not necessarily a problem, but are a specific source of insight. By identifying tensions and treating them as opportunities for further exploration and learning, decision making on integration and boundary setting can be enhanced, both in terms of logic (which inevitably involves prioritising some purposes and values over others, given that comprehensiveness is impossible) and in terms of transparency to stakeholders, who include food system participants, RCUK and other researchers.

1.3 Purpose

Accordingly, the purpose of this work is to develop and apply a process of reflection on boundary judgements with each of the projects within the GFS-FSR programme. Very little budget was available, so it was agreed that the process would be light touch, and would focus only on the *identification* of boundary dilemmas in and across the research projects. This work aims to provide the basis for a future application for funding to RCUK to go one stage further: to work with research teams to *resolve or better manage* boundary dilemmas through values-based dialogues within research teams and with stakeholders, taking account of power relations and the rich interconnectedness of food systems. The results of the light touch boundary reflection process will be presented in this report, and the report will be delivered to the Oxford team to support their project co-ordination and integration roles.

1.4 Objectives

The objectives are thus to:

1. Develop and apply a light touch process of reflection on boundary judgements across the projects within the GFS-FSR programme.
2. Examine the ways in which differences of opinion on system boundary judgements and openness (or lack thereof) to reflection and revision has impacted individual projects.
3. Integrate the results of the light touch boundary reflection process to:
    a. Identify potentially conflicting recommendations and analyse them in terms of the dilemmas they pose across stakeholder groups, issues, sectors, scopes and scales.
    b. Identify synergistic recommendations across stakeholder groups, issues, sectors, scopes and scales.
4. Provide a preliminary assessment of the impacts of the reflection process both within and across programmes.

1.5 Structure

This report is structured as follows: Section 1 comprises this introduction; Section 2 provides the theoretical framework for the work; Section 3 provides the methodological framework applied; and Section 4 provides the results obtained. Finally, Section 5 provides concluding remarks and directions for future research.

2 Theoretical Framework

2.1 Systems Thinking

"How can we design improvement in large-scale systems without understanding the whole system, and if the answer is we cannot, how is it possible to understand the whole system?" (Churchman 1968a)

This question sums up one of the fundamental challenges faced by the GFS-FSR Research Programme – and indeed, the first meetings of the programme attempted to define 'the whole system'. As far back as the 1960s, Churchman's answer was that we cannot apprehend the 'whole system' in any objective sense, and we make value-laden judgements about what to include and what not to include. He also explained that these choices have power since they determine the assessment of improvement, and there is therefore an ethical dimension to how they are made. Since then, a stream of systems research has centred on dealing with boundary explorations and boundary setting. Work directed at securing improvements in food systems can benefit from this 50+ years of theory and practice.

Systems thinking itself originally grew out of a desire for comprehensiveness, to understand 'the

whole system' through systems science. However, comprehensiveness is challenged because comprehensive thinking on social and ecological issues "can find no natural boundaries" (Ulrich 1993). As everyone in the GFS programme appreciates, there is increasing awareness of the links that exist between physical, social, economic, political and ecological systems at all scales (Gunderson and Holling 2002). These cross-scale, cross-sector, cross-discipline links make the setting of boundaries, when seeking to understand or to intervene, "difficult and often highly contentious" (Midgley 2000b).

In fact, because of these interconnections, comprehensiveness would imply expanding our system boundaries to include the World and God and everything, or otherwise be left with a problem that is incompletely specified because something relevant has been left out of the analysis (Ulrich 1983). This is what Ulrich refers to as "the problem of holism" since "the holistic imperative of "considering everything relevant" is philosophically as inescapable as it is impracticable" (Ulrich 1993).

This is certainly the case when it comes to the UK food system. If we were to include in our analyses everything that contributes to the supply and/or consumption of food in the UK, then this potentially includes the entire planet, given the globally interconnected and multi-scale web of issues that have an impact. These issues range from geopolitics, trade and climate change, through to local socio-economic conditions, and even the chemicals in water and microbes in the soil.

Each of the 13 projects within the GFS programme, driven by different inquirers with different purposes, values and backgrounds, is making different system boundary judgments. Each of these boundary judgements could be considered to be like a lens through which they look at the world, picking out some features of reality to be examined and inevitably leaving out others. The interdisciplinarity in the projects may help to expand the remit compared with a single-discipline approach, but nevertheless interdisciplinary teams still have a bounded perspective. Figure 1 provides a visualisation of this.

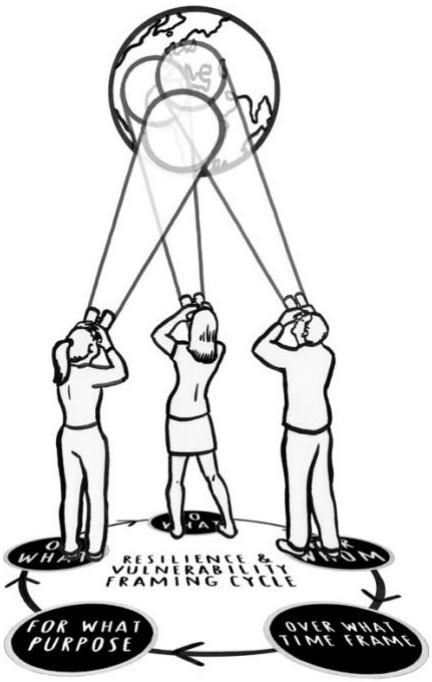

Figure 1 Each GFS-FSR project takes a different lens on 'resilience of the UK food system'; image from Helfgott (2018)

No food system study can include absolutely everything relevant, and every project inevitably makes

decisions on what to include in or exclude from their focus, as shown in Figure 2. In some cases, there are differences of opinion about these decisions within the project teams; between those teams and the Oxford coordination team's vision of food systems research; and between the researchers, their funders and stakeholders. There are often even more differences within the various stakeholders of each project, given the diversity of purposes and values these stakeholders bring into their engagements with the research. Decisions on focus, and the differences between stakeholders, are an inevitable feature of dealing with complex food security issues.

In terms of systems theory, it is important to be aware that every boundary *simultaneously enables and constrains*: it enables the researchers to get a manageable project done, taking account of a particular set of purposes and values, while at the same time constraining what the research can account for in terms of other purposes and values linked to issues that are placed outside the boundary of concern (Lissack 2017; Midgley and Lindhult 2017).

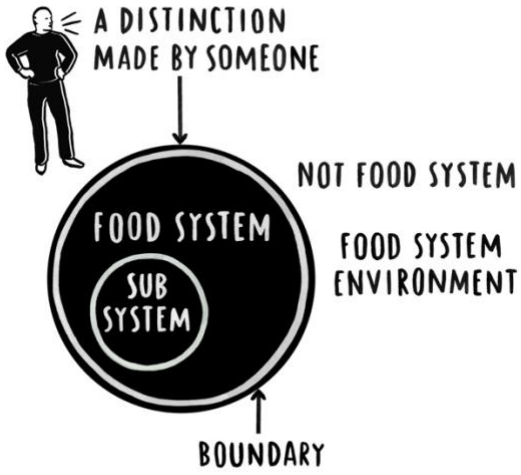

Figure 2 System Boundary Judgements

Systems thinkers acknowledge that those involved in understanding or modelling human and natural systems make judgements about what is important to include in the analysis and what can be regarded as being in the system's environment. These judgements are influenced by the inquirer's purposes, the methods they use, the information/data available, their education, their social and cultural values, what stakeholders they are engaging with, and a range of intangible factors. What belongs to the 'whole system' is entirely dependent on and relative to the inquirer's choice of conceptual boundary (Ulrich, 1983). As such, whenever we speak of a system, it should be obvious that we are not speaking of transcendent reality (Matthews, 2004), but our *partial* understanding. In English, the word 'partial' has two meanings, and both are relevant to our boundaries of understanding: 'incomplete' and 'dependent on a purposeful value judgement about what is important'.

The boundary judgements made in any given project inform the food system models subsequently developed and, therefore, our understanding of that portion of the world (Churchman 1968b). Accordingly, the ways in which system boundaries are drawn, and how they are linked with our purposes and values, determine what constitutes desirability and improvement. The boundaries ultimately enable the production of knowledge, often in a manner that feeds back to reinforce rather than challenge those boundaries (Velez-Castiblanco et al. 2016), thus disabling the production of

alternative forms of knowledge that might have been developed in light of different boundary judgements. Eventually, the boundaries give rise to partial (limited and values-dependent) conclusions and recommendations for action.

This is unavoidable, and it tells us that we need to do better than take our initial purposes, values and boundary judgements for granted. The best we can do is explicitly think about other possible boundaries, other stakeholder perspectives, and other aspects of the world that could be affected by what we choose. *Full* comprehensiveness is forever out of reach, but *greater* comprehensiveness than we currently have is always possible if we are willing and able to spare the time and energy to engage in further learning.

Accepting that boundary judgements are inevitable, normative and affect our conclusions and recommendations for action implies that we should progress with humility, in a reflective and iterative manner that involves those whose lives might be affected by whatever intervention we might propose. Diverse participation in a transparent process of systemic boundary critique is actually a requirement for scientific rigour, since it is clear that we cannot rest on indefensible claims of comprehensiveness, and even observations that are universally accepted as objective are dependent on prior, normative boundary judgements about what it is appropriate to research (Ulrich 1983; Midgley 2000b, 2003, 2008; Fazey et al. 2018).

The stopping point for this process of critique is inevitably a pragmatic judgement, taking account of the need to be inclusive of different stakeholder understandings, be transparent about our boundary judgements to others, and still complete a project with limited resources in a given period of time. Ulrich (1983) argues that, if the process of exploring possible boundaries has to end before agreement between stakeholders is secured, the researcher has an obligation to make the reasoning for this explicit, so future readers understand the pragmatic compromises that have been made and are aware of what has been excluded from consideration as a result.

2.2 Food Systems

Like systems thinking itself, thinking about 'food systems' arose from a desire to overcome narrow ('siloed') and reductionist thinking – in particular, an overly-narrow focus on food production, and a definition of food security focused on calories, which led to numerous unintended consequences; failed to address the full range of issues contributing to the availability, access and utilization of food for different groups; lacked the capacity to address 'wicked problems' (issues characterised by high levels of complexity, uncertainty and conflict); and failed to create the systemic transformations needed to shift an unsustainable, unhealthy and inequitable status quo.

Developments in food systems thinking have led to many conceptual frameworks for understanding 'the food system'. A fundamental shift in thinking occurred with the framing of food systems in terms of a set of food system activities, of which production is only one step, and which include processing and packaging, storage, transport, wholesaling and retailing, consuming and disposing and reusing of food. This move beyond a production focus is illustrated in Figure 3.

Later versions of Figure 3 acknowledge that consumption patterns impact retailers, which in turn impact producers. In fact, while the earliest food system diagrams of this kind look rather linear and unidirectional in terms of the activities, there are feedbacks between all of these activities, and opportunities for direct connections between any sets of actors: producer and consumer, retailer and farmer. Consumers themselves can become producers and distributors, consumers can collect waste from retailers and redistribute it to other consumers, and indeed any combination of actors and network architecture is possible, and most combinations already exist somewhere (Sonnino and Marsden 2006; Helfgott and Vervoort 2018). We are dealing with *value creating systems* rather than linear value chains (Ramírez and Mannervik 2016).

Figure 3 Food System Activities (Ingram 2011)

These food system activities produce food system outcomes, as shown in Figure 4. Which food system outcomes are/should be focused on has also been a topic of debate. The early focus on food security as the primary outcome of relevance from the food system has been augmented with a focus on food *and nutritional* security, and also (depending on the study) with other social, economic, political and environmental outcomes that the food systems also produce (see also Figure 6).

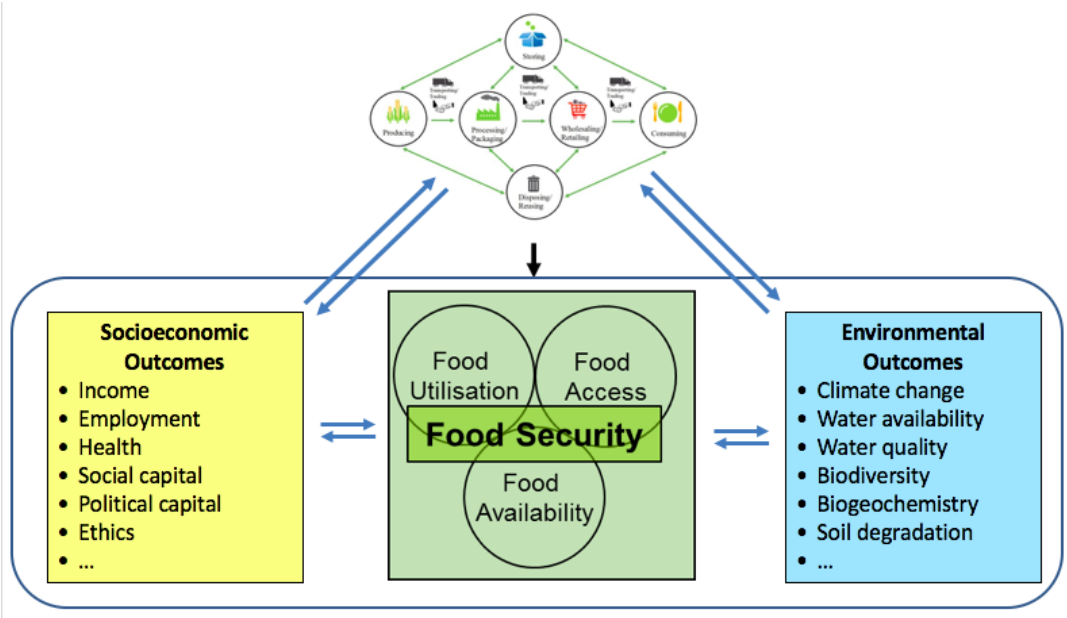

Figure 4 Food System Activities Produce Food System Outcomes (Ingram 2011)

Food system activities are conducted by food system actors and exist within a particular environment. The conceptual framework shown in Figure 5 highlights the biophysical environment, plus science and technology, that enables food system activities, the policy environment, the market environment and how social structures and organisations impact food system activities and outcomes.

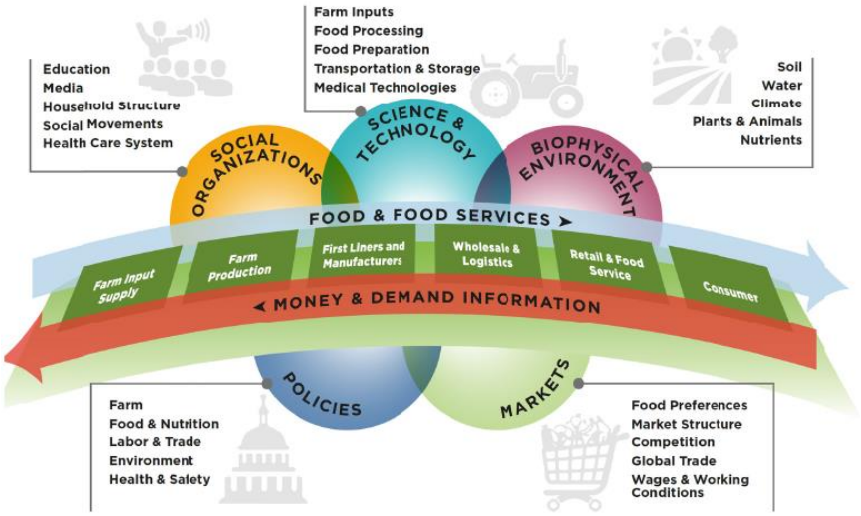

Figure 5 Conceptual framework showing the range influencing 'environments', image provided by John Ingram

Which aspects of the world are considered 'internal aspects of the food system', and which are considered 'external factors' and relegated to the environment is an issue that has been approached quite differently by different research programmes. Figure 6 shows an example from a European food system research programme stakeholder workshop, which makes a number of interesting boundary choices. For example, it places science, technology and policy outside the food system, but includes the system outcomes within the system. Both of these judgements could be open to question.

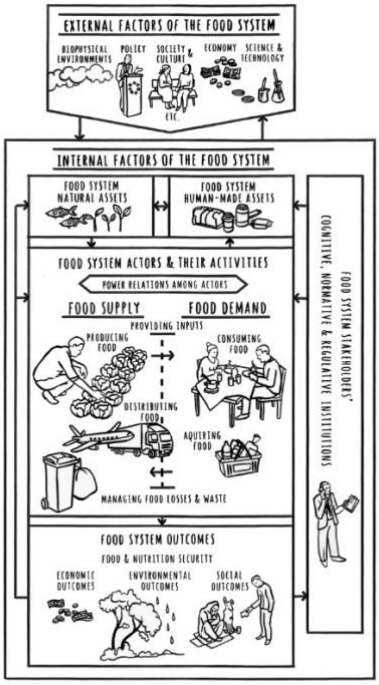

Figure 6 Food System Conceptual Framework Generated within EU FP7 Transmango Workshop

Contrast the above with the SUSFANS conceptual framework, shown in Figure 7, which includes major EU food system goals (see the blue-bordered box on the bottom left). Also, the food system outcomes shown in the green box are conceived as external impacts/outcomes *and also as drivers*.

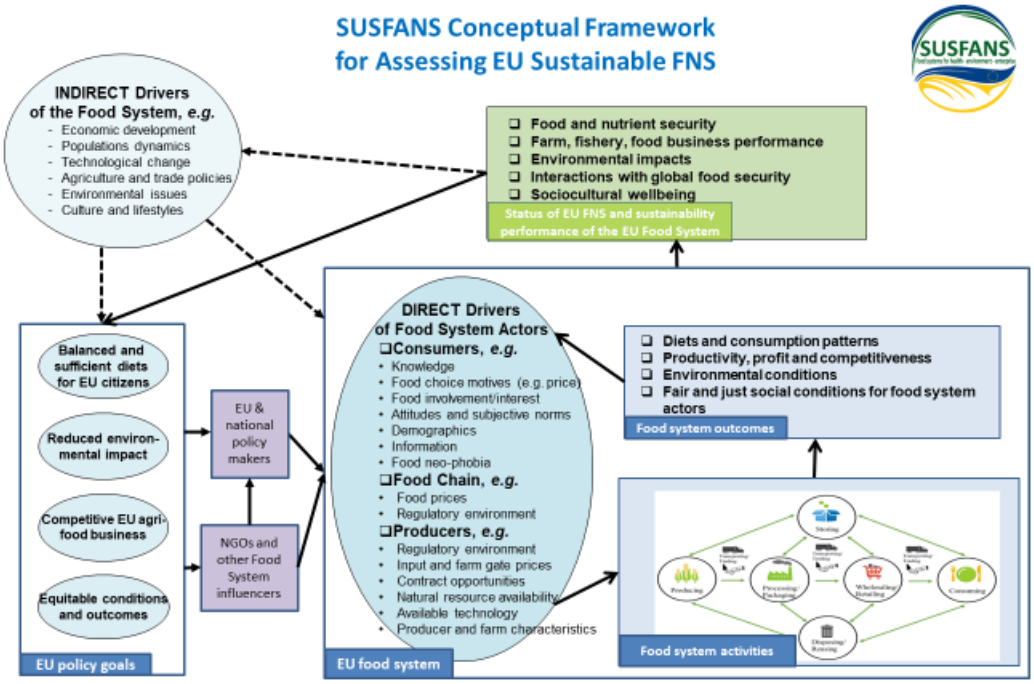

Figure 7 SUSFANS Conceptual Framework

The diagrams above highlight that attempts to define the boundaries of food systems are also impacted by focal level and resolution – are we looking at the globe, Europe, the UK, the system of direct arrangements between farmers and consumers in a particular locality, or an abstract food system? And even with any one of these, there will be many different ideas about what to include and exclude, and what details are relevant.

The need to move beyond a narrow focus on increasing or maintaining production without consideration for the relationships with other food system activities, environments or outcomes is becoming increasingly clear. However, what is less clear in each context is where the boundaries should be drawn on what is included within the food system under consideration, what should be considered external, and which outcomes are relevant. Each of these diagrams illustrate the "distinction made by someone" part of Figure 2.

3 Methodological Framework

The methodological framework used here for reflection on boundary judgements is informed by Critical Systems Heuristics (CSH) (Ulrich 1983, 1987), and the approach to boundary critique advanced in Systemic Intervention (Midgley 2000a).

CSH involves a set of 12 questions that both 'experts' and ordinary people alike can use to help surface boundary judgements. These questions fall into four categories:

- *Motivation*: Where does a sense of purposefulness and value come from? What are you concerned about and what is your purpose in seeking to understand or intervene?
- *Power*: Who is in control of what is going on, and has power of veto? Who has control over preference shaping, agenda setting and decision making within the project? Who determines the measure of success? What do different groups of people have a say over?
- *Knowledge and expertise*: What experience and expertise are involved? What forms of knowledge are necessary, and from what sources?
- *Legitimacy*: What is the basis of legitimacy within the project (positional authority, scientific methods, democratic processes, consensus, end user backing, etc.)?

These four areas, as phrased above, are about the question of *what is the case* in relation to a particular project. However, it is equally important to be able to ask, *what ought to be the case?* This statement stems from Ulrich's recognition that questions of 'is' and 'ought' are both essential in research, and the drive in mainstream science, advocated by Popper (1959) amongst others, to focus only on observables (and theoretical postulates dependent on observables) effectively marginalizes half of legitimate inquiry (about the morality of what ought to happen, including what ought to be researched) to the realm of 'non-science', or politics (Ulrich 1983). The danger in this marginalization is that vested political interests can easily take control of research agendas (for example through funding mechanisms and overly-simplistic ideas of serving end users) when morality is not up for scrutiny as part of the scientific endeavour (Ulrich 1983; Midgley 2003, 2008).

In the case of our current research, the emphasis was very much on 'what is' within the projects (as our goal was to explore boundary dilemmas before applying for funding to find ways to deal with them), but of course what the participants drew to our attention was often a result of dissonance between what is and what they thought ought to be. The two are always strongly interconnected.

Midgley's work on boundary critique in Systemic Intervention builds on CSH and its 12 questions in the four categories (Midgley 2000a). Midgley overcomes a number of pragmatic difficulties with implementing CSH, not least of which is the specialist academic language used in the original 12 questions, which Midgley has rephrased in plain English[1] (Midgley 2017). Also, he takes the reflective process further, acknowledging that consensus or accommodations between stakeholders can often mask a process of marginalisation of different purposes, perspectives and values. By revealing marginalization, boundary dilemmas become more visible and can become opportunities for learning.

Accordingly, we developed a simple, light-touch process to explore the ways in which motivation, power, knowledge, expertise and legitimacy were specified within each project; how that impacted on the inclusion, exclusion or marginalization of different issues and stakeholders; and what the consequences of this were. This process was implemented in two stages.

Stage 1 comprised a workshop activity in which the Principle Investigators (PIs) of each project were asked to reflect on inclusions/exclusions of perspectives, stakeholders, issues, values and ethics; and on the consequences of these choices. The reflection was at first undertaken individually with the aid of a handout asking questions to prompt the thinking of the PI (see Appendix B). Then, in small groups, the results of the individual reflections were shared with the PIs of the other projects, and feedback was noted down by the individual PI. Membership of the small groups rotated until everyone had received feedback from everyone else.

Stage 2 comprised a set of semi-structured interviews with participants from each of the projects. Mostly, we were able to speak to two individuals from each project, but not in every case. The semi-structured interviews allowed participants to describe and discuss boundary issues in more detail than

1 The original phrasing of the 12 questions is included for reference in Appendix A.

in Stage 1, and we facilitated further exploration and reflection during the interview. The Stage 1 results were used to inform the questioning by the interviewer in Stage 2, so the interviews didn't just go over old ground. The interview questions related to Ulrich's categories in the following ways:

1. Participants were asked, in their own words, to describe the purpose(s) of their project, and their own personal motivations for undertaking the work. This relates to Ulrich's category of *motivation*, and was about how the purposes of individuals shaped the framing of the project.
2. Participants were asked to describe the scope of the project in terms of what was included in and excluded from their analyses, and the how and the why of this, as best they could. The same questions were asked with regards to the inclusion and exclusion of different stakeholders. In both cases this included a discussion of the role of different types of *knowledge and expertise*, and also contributed to understanding *power*, as well as providing space to support the interviewees in their direct boundary reflections.
3. Participants were asked if they recalled any instances in which disagreements arose, within the team or with different stakeholders, about the inclusion or exclusion of anything (issues, values, stakeholders, etc.); how these disagreements were resolved; and what impacts they had, including new insights. This addressed Ulrich's categories of *power* and *legitimacy*, and also contributed to direct boundary reflections.
4. Finally, participants were asked to describe any situations in which they had to carefully manage stakeholder relationships, including the reasons for this and the impacts it had. This covered Ulrich's category of *legitimacy*, as well as contributing to the interviewees' direct boundary reflections.

The semi-structured interview guide is provided in Appendix C. The content of the interviews was analysed to provide a qualitative mapping of the frames of each project relative to one another, covering purpose, scope, scale and resolution. Where possible, systemic analyses (i.e., looking out for where the knowledge generated by each of the projects might interact when brought together to enable whole programme reflections and recommendations) were used to identify potential synergies and tensions to be managed across focal issues, scales and levels. However, this aspect could not be anywhere near comprehensive due to the limited resources for this research, and we would anticipate that a future, larger project would have as one of its objectives research into how programme-project relationships can be managed systemically to ensure that both the parts (projects) and the whole (programme) can work synergistically.

4 Results

The investigation clarified how the 13 projects within the GFS-FSR programme differ in purpose, scope, scale and resolution. These results are summarized in Section 4.1. Each of the projects makes different, although sometimes overlapping, boundary judgements. These differences lead to different conclusions and recommendations for action. The tensions and synergies between the projects in this regard are summarized in Section 4.2. It emerged that an important distinction amongst projects relates to whether the projects focused on maintaining or improving an existing set of system activities or architectures, or on maintaining or improving systemic outcomes. Those projects focused on systemic outcomes differed in the degree of abstraction used. The discussion of existing activities and systemic outcomes is covered in Section 4.3. Finally, Section 5.2 addresses the role of reflection on system boundary judgements within each of the projects. This is later used by us to draw out conclusions about the potential future role of systemic boundary critique in food system research in general.

4.1 Different purposes, different scopes, scales and resolutions

Each of the projects takes a distinct lens on the UK food system. Though there are overlapping elements, each has a distinct purpose, scope, scale and resolution, and each makes different boundary judgements. These are summarized in the following subsections.

4.1.1 Purposes and Measures of Success

The following statements of purpose and measures of success, summarized in Table 1, have been extracted from the semi-structured interview material. The purposes and measures of success for each project shaped the choice of inclusions and exclusions in terms of scope, scale(s) and resolution.

Table 1 Purposes and Measures of Success for the GFS-FSR Projects

Project	Purpose(s)	Measure(s) of Success
BananEx	To understand the effect of abiotic (weather, climate change) and biotic (disease) shocks on the banana production system, and the transmission of shocks through the value chain. To quantify the resilience and robustness of the supply chain to shocks via analysis of production and price time-series. To improve understanding of the biology of a major banana pathogen (Fusarium Wilt Tropical Race 4) and develop novel control methods. To link stakeholders across the supply chain from producers to retailers, in collaborations that improve the resilience of banana supply.	Increased knowledge of how abiotic and biotic factors affect global banana production. Increased knowledge of how these shocks affect prices along the value chain. Increased engagement with stakeholders (producer organizations, importers, retailers) in contributing to sustainable production and trade of bananas. Increased understanding of banana production and trade issues among consumers.
FF&V	To understand how water scarcity impacts the supply of fresh fruit and veg (FF&V) into the UK market in terms of tonnage of crop and how this relates to the financial viability of the growers and the other actors. This is because water scarcity in both the UK and in other countries risks supply of FF&V into the UK market. Arising from that, the project has a purpose of asking, what are the mitigation strategies that can be put in place throughout the supply chain to deal with water scarcity? To what extent are different mitigation strategies preferred by different parts of the supply chain? And are any different mitigation strategies contradicting each other or the interests of different actors?	Maintaining the capacity of the FF&V supply chain to meet demand for FF&V from the UK market in terms of tonnage in. A good outcome is a supply system where the benefits gained for one actor group in the value chain [from mitigating water related risks] are compatible with benefits for other actors in the supply system. The project is looking for win-win all the way through the value chain. If the consumer is

	This applies to maintaining the capacity of the *existing supply chain* to supply FF&V to the UK market in the face of water scarcity.	benefitting at the expense of the grower, for example, that would be a less desirable outcome.
I Know Food	Driven by passion about the food system and making it more sustainable. The purpose of the project is to integrate the knowledge and perspectives of disparate food system actors involved in the entire value chain of particular commodities, such as soy, fresh fruit and veg., etc., in order to enhance overall system resilience ('system' here means the entire value chains of these commodities) by removing disconnects between various actors in the system and providing communication and decision-aiding knowledge and tools that work to manage trade-offs and make the most of synergies.	The measures of success are better knowledge, understanding and communication of and between food system actors (policy, industry and third sector); better integrated value chain management; improved farm innovation processes; more sustainable food systems; and better food and nutritional security.
Pig Sustain	To bring together diverse expertise including data analytics, social and economic sciences, computer science and engineering, veterinary sciences and biological sciences, to look at the future of the UK pig industry from multiple angles, overcome one dimensional solutions and look for an integrated and systemic approach to the resilience of the industry.	Increased understanding of how historic shocks and trends have impacted the pig industry from farm to fork. Increased ability to detect emerging disease early, for improved sustainability through animal health and welfare. Improved consumer data-led decision-making enabled for food system actors and policy makers. Increased engagement with stakeholders (producer organizations, processors, retailers, policy makers) in contributing to sustainable production. Whole industry resilience models enable prediction of the industry's response to future shocks and the impacts of mitigation strategies. Should

		be able to describe past events well enough that they can be used to extrapolate into the future to explore the impacts of potential future shocks.
RUGS	This is a model-based project. The purpose of the project is to evaluate the effect of shocks on the global food system by extending and using existing coupled models.	Success is when the models are able to usefully incorporate greater complexity and feedbacks between production methods, consumption patterns, climate, land-use, policy and economics. The models should be able to describe past events well enough that they can be used to extrapolate into the future to explore the impacts of potential future shocks.
Pollination	*"We are concerned about the resilience of pollinator services and pollinator natural capital in the UK. Anything which puts pressure on the land to produce more is going to put pressure on biodiversity."* The purpose is therefore to use modelling techniques to determine the optimal land-use situation for the UK to guarantee an adequate spread of pollinators throughout it. Further, the project seeks to answer the following questions: Will we have enough pollinators where we need them? Will we have the right insects for the right crops as our tastes change? Will pollinator populations be able to withstand changes to the way we manage land? What might be the costs to us, socially and economically, if we get it wrong?	Being able to present the optimal land-use situation for the UK to guarantee an adequate spread of pollinators. The presentation is to stakeholders, because the project team believes it is an important part of the conversation and an important part of decision-making to know the difference between what would be ideal from a pollination perspective and what currently is the case. This will be able to inform knowledge about what would be good to aim for by way of pollinator spread.
SEEGSLIP	The purpose is to provide an evidence base for sustainable livestock practices and understand what it would take for farmers to want to practice them.	Increasing numbers of livestock farmers choosing ecologically sustainable practices.

	This project is specifically focused on demonstrating the 'ecologically' sustainable viability of sustainable livestock approaches.	
Dairy	The purpose is explore the trade-offs between farmers' livelihoods, the natural environment and the stable supply of reasonably priced dairy products, to find better ways of working in the face of unpredictable future societal, environmental and climate change.	Measurable improvements in environmental sustainability and long-term security of milk supplies. Indicators provided in the post-award impact plan. Early warnings of major, notifiable or new and emerging animal diseases in the diary sector. Enhanced provision of ecosystem services from dairy and other land uses based on the adoption of private-public payment for ecosystem service schemes.
ResULTs	The purpose is to find out how to secure thriving communities in the upland areas of Britain, through sheep and beef production. This project isn't just about food security in terms of tonnage / how much sheep and beef make it into the supply chain. The project is about the upland areas themselves. Upland areas supply relatively little of the sheep and beef in the food system, but these areas, people, communities and environments matter. The project is addressing the question, what would happen if we got rid of sheep and beef in the uplands?	Prosperous, healthy, happy and sustainable communities.
RePhoKUs	The purpose is to integrate knowledge across disciplines and sectors in order to achieve sustainable phosphorus (P) use, support the food system and deliver ecosystem services such as clean water and biodiversity. To bridge gaps between systems of understanding: chemical cycles, farming systems, ecological systems, socio-cultural systems, economic systems and policy and	Multiple measures of success: (a) to start a conversation about the need for more sustainable P use and to empower stakeholders to take action; (b) to develop the idea that some regional governance of P is required beyond the farm gate to enact P sustainability; (c) down the line success would be measured by

	legislative frameworks in the service of this purpose. Finally, to reduce the vulnerability of the UK food system to a possible P scarcity in generations to come.	a reduction in P inputs to the food system, greater efficiency of what P is used, lower surpluses of P and lower losses of P discharged into the environment; (d) development of regional and national strategies to combat P scarcity in the future.
T-Grains	The purpose is to improve health and nutrition outcomes through better consumer-producer relationships. The project vision is that, through digital technologies, we can enable awareness of food system trade-offs and help people to make more informed choices. The focus is on health and sustainability and identifying and negotiating any tradeoffs that exist between these two types of outcome. The project hopes to develop tools and approaches that make consumers more aware of the constraints or the implications of their food system choices.	Better and digitally enabled relationships between producers and consumers. Increased trust between food system actors through better relationships. Consumer empowerment through information tools that make them aware of the health, social and environmental implications of their food choices. Consumers making more sustainable and healthy food choices. Better food and nutritional outcomes.
Diverseafood	The purpose is to investigate how we can diversify production from aquaculture and diversify consumption of seafood in the UK. The goal is to look at more sustainable and more healthy production – even though there are trade-offs between these two aims.	Removal of social, economic, policy and legislative barriers to the uptake of Integrated Multi-Trophic Aquaculture (IMTA) systems. Greater uptake of IMTA. Better nutritional outcomes from seafood in diets. Significant reduction in the environmental impacts of aquaculture through IMTA.
Rurban Revolution	The purpose of the project is to simultaneously reduce diet related illness, poor diet choices and dietary inequality issues (such as access to	The measures are improved dietary choices, improved physical and mental health

	fresh fruit and veg) while addressing mental health issues, community cohesion and sustainability through urban horticulture.	outcomes in the target communities, improved community cohesion, lower environmental impacts of food consumption.

4.1.2 Scope and Scales

The summaries of the scope and scale issues in Table 2 are based on descriptive material and conscious inclusions and exclusions extracted from the semi-structured interview material.

Interviewees always referred back to their purposes and what they hoped to achieve when justifying their choices of scope and scale, and their choices to include or exclude certain features of reality. The projects have very different scopes, scales and resolutions.

Table 2 Scopes and Scales of GFS-FSR Projects

Project	**Scope**	**Scales/Levels**
BananEx	The supply chain of bananas from Latin America and the Caribbean to the UK, from producers to purchasers, importers, retailers and consumers. Other stakeholders including global quasi-governmental organizations (UN FAO), NGOs (Banana Link) and producer organizations (e.g. ASBAMA, Colombia).	International (climate change, trade) to local (responses of individual banana plants to weather and diseases).
FF&V	The supply chain of FF&V to the UK market, water availability, mitigation strategies of existing supply chain actors for dealing with water scarcity. All post food manufacture and post retail consumers are excluded. The project is not looking at demand. Also excluded is the pre-farm system, and impacts on farm workers and other labour is not being considered. In terms of the risks, a conscious decision has been made to focus on water scarcity rather than flooding, water logging, salinization, etc.	Farm level, catchment level, National level, the level of bilateral international trade agreements.
I Know Food	The entire value system from production through consumption for certain commodities: soy, sugar, maize, cocoa and fresh fruit and veg	Down to the UK farm level when looking at innovation; up to the international level looking at trade; global and

	for the UK. FF&V was added later at the request of DEFRA due to Brexit. Social, economic, environmental outcomes of these activities are included. Related social, economic and environmental policies in the UK are included. Social, economic, environmental outcomes of the food system are included. Food and nutritional outcomes are included. This project takes a flexible attitude to boundaries, and have let them evolve as they have unpacked key structural, informational and institutional obstacles to resilience. DEFRA, Food Industry (e.g. the Co-op) and farmers are beneficiaries.	local when looking at environmental outcomes; and national when looking at social and health outcomes in the UK. Resolution is individual actors within the value system and individual commodities.
Pig Sustain	The entire value chain from production through to retail (and indirectly consumption) for pigs in the UK. Focus on producers and processors, retailers and consumer behaviour. The project looks at multiple disturbances including climate change, Brexit, etc. Include health, sustainability, labour and profitability.	Farm through to national level, with international level considered for trade networks.
RUGS	The model includes detailed spatial representation of crop and pasture yields for a range of intensities (fertilizer and irrigation rates). It also incorporates two-way interactions between climate and the global food system. Climate change affects crop growing conditions, especially the probabilities of extreme weather events, and will influence producer adaptation to changing conditions. But climate is also affected by land use, and a substantial proportion of the total anthropocentric carbon dioxide emissions are associated with land use change. To represent the feedbacks between land use and climate, the project's model framework includes a coupled climate system model, vegetative model and land use model. It is not an equilibrium model, and is able to	Physical: global, national, farm. Legislative and regulatory: international, national. Economic: global, national, market sector, crop. Levels in the value chain from producer to consumer.

	represent non-economic governmental response behaviour; e.g., the imposition of trade barriers due to supply shortages. Shocks relate to supply and price volatility. Policymaker, industry and supply chain stakeholder interventions to potentially increase the resilience of the UK food system are examined, based on the simulation results. The project will also consider the effect of market power, and the policy and regulatory environment.	
Pollination	Land-use modelling of the entire UK; linked modelling of pollinator populations; social, economic and environmental impacts of different land management options; various policies impacting land-use; farmers' attitudes; Stakeholders include the National Farmers Union, Natural England, DEFRA. Excluded stakeholders: pesticide and chemical companies, such as Bayer and Syngenta.	Scales: Physical: National, landscape, farm. Legislative and regulatory: Environmental and agricultural policies – Regional, national, local. Social: Sector, community, farmer. Ecological: population, community, ecosystem. Resolution: "a very fine spatial scale".
SEEGSLIP	The project includes a range of farmers who are Pasture for Life (PfL) members, all with very different reasons for having an interest in sustainable livestock practices. Non-PfL farmers are not included. A range of PfL practices are being examined, including the social, environmental and economic impacts of these practices. Environmental considerations include grass species, nitrogen and phosphorus. The project includes the role of collaboration and community in providing economies of scale. It is undertaking a detailed examination of different farmer mind-sets and what would be needed to assist farmers to make environmental decisions.	Social: individual farmer, community, PfL network. Policy, legislation: local, national. Physical: farm, district, nation.
Dairy	The project focuses primarily on dairy production systems, considering a range of	Empirical research: from field to farm scale.

	management inputs and interventions that can improve the resilience of supplies to processing plants. Outputs from the production system are considered primarily in terms of milk production, animal welfare and ecosystem services, and the social drivers and implications of these changes are considered in depth. These outputs are integrated at a landscape scale via Bayesian modelling and in the aggregation of demand from local businesses for natural capital and ecosystem services that can be delivered from dairy and surrounding systems. At this scale, investors are offered a portfolio of options to reduce business risk and increase resilience of supply (e.g. of fresh milk or clean water) that integrate ecosystem services from across the landscape, including from neighbouring woodlands and peatlands.	Modelling: landscape scale. Economics research and impact: national scale.
ResULTs	The project is focused on sheep and beef production, and excludes other livestock species and other forms of agriculture/horticulture because there are few opportunities to diversify production due to climate, topological and soil limitations. The people who supply goods and services to sheep and beef farmers are included: vets, feed suppliers, shepherds, stockmen, machinery suppliers, abattoirs, people who buy the animals – sometimes other farmers; follow the supply chain to different market routes through to the supermarket. Include environmentalists, and local development agencies such as Councils, or other significant organisations; also include consumers. The project is not looking at tourism, energy production, forestry and other livelihood options, although the team is aware that they impact on the capacity of upland communities to thrive. However, the project does look at how these things (e.g., tourism and forestry development) impact on agriculture. They are outside the system boundaries from the point of view of the detailed research, but are included in the project as 'pressures'. The project is also looking at the regulatory and institutional contexts.	Community level, farm level, value chain. Focus on upland communities in the UK in specific areas.

	The project takes a systems approach within these boundaries, looking for trade-offs and synergies across social, economic, environmental and political dimensions of upland beef and sheep farming.	
RePhoKUs	The project looks at entire catchments and regions to understand stocks and flows of phosphorus across the entire food chain: it includes the ecosystems, water, all of the farming and processing activities therein, and how these are shaped by policies and laws, the culture of the farmers, the agri-food industry, the wastewater sector, current understanding and the access to information and technology, how food production and consumption practices produce subsequent environmental impacts via phosphorus, and how they might be impacted by a scarcity of phosphorus. There is also national level work on farming, processing, ecosystems, water and phosphorus, including scoping multiple stakeholder knowledge gaps and potential for transformational change in use of phosphorus or capacity for system redesign. The project examines dietary phosphorus consumption patterns and the impact of future dietary trends on the phosphorus entering wastewater treatment centres, and subsequent effluent discharge loading and water pollution.	Multiple scales: physical, ecological, social, legislative and regulatory to name a few. The resolution goes from molecules to the entire nation. “Some of our focal levels are molecule, farm catchment, river basin, national – these levels themselves occur on different scales. Even this list is a mixture. There is also the food system scale, in terms of different types of actors involved in different food system activities. It’s hard to define the boundaries of each of these levels, and how the scales and levels are situated with respect to each other is complex. This has itself become a topic of discussion and research, and we have written a paper on this".
T-Grains	The project focuses on CSAs as a means of examining the impact of direct relationships between producers and consumers. This includes how CSAs play a role in changing food culture. The project is not including other forms of changing household food culture, like school gardens. This project considers “regional” food systems, and “region” has a very defined geographical limit: 100 square km.	Focus on specific, limited geographic regions. Focus on CSAs.

	Includes food and nutritional security, social and environmental outcomes.	
Diverseafood	The project includes both production of seafood via aquaculture in the UK, and consumption of seafood through any means in the UK. The boundary is the UK in terms of both production and consumption. The project includes a limited number of species and production systems, including salmon, mussels, seaweed, etc. The main focus is on salmon, as it has the largest market share and most significant environmental impacts. The project looks at what it would take to increase sustainability, health and nutritional outcomes through Integrated Multi-Trophic Aquaculture (IMTA) systems, from many dimensions – social, cultural, economic, political and environmental. IMTA outputs from one species get used as the inputs for others, so you get a recycling of nutrients and it is possible to create a neutral system. Social, cultural, legislative and policy barriers and incentives to this are included. Various business models for making these systems viable are included. The consumption side is included to see what can be done to diversify demand and ensure integrated systems are economically viable. The project also looks at nutritional outcomes of different farming methods, and of each of the seafood species, and the nutritional value of diets, which are diversified. The stakeholders engaged include producers, retailers, consumers and policy makers. For the business model work, the researchers are speaking with producers and actors at different levels in the supply chain. For ecosystem services and policy work, they are also covering social license to operate. They are speaking with two communities in two areas in Scotland. Speaking with the public in those areas will help the project find out what	National, regional and “farm”. Focus on specific commodities.

	gives or takes away the societal license to operate. The project is also talking to local councilors, the tourism sector, fisheries, and all people that have a stake because of their interaction with aquaculture, such as environmental agencies, Marine Scotland, etc.	
Rurban Revolution	Urban horticulture, nutrition, physical and mental health of communities, community cohesion, related policies.	City.

Note that a detailed stakeholder mapping would not be possible without more data, and is outside the scope of this particular project due to the time and funding allocated.

Table 3 (below) is based on both issues and stakeholders included and excluded. It maps out which food system activities and outcomes are covered in each GFS-FSR project.

A number of things can be observed in Table 3:

- All projects include production
- No projects include all food system activities
- No projects deal with post farm-gate food waste other than RePhoKUs, which is just focused on phosphorus in waste water
- Most projects deal with some environmental impacts of a subset of food system activities
- A minority of projects look at nutritional security

This table cannot show the weight given to the different issues covered in the various projects. The interviews nevertheless revealed that the projects are heavily production focused. Some interviewees mentioned that they specifically avoided consumption due to difficulties researching this.

Another detail which is clear in the interviews is that the majority of projects are commodity focused; only RePhoKUs, Pollination and (to some degree) T-Grains and resULTs are not. It becomes practically feasible, though still an enormous task, to look at the entire value system for a specific commodity. Concomitantly, RePhoKUs, Pollination and T-Grains appear to include a comparatively limited number of human activities in the food system, but they look in great detail and complexity at interactions and outcomes within the remit of what they are covering. For example, while the RePhoKUs project officially includes few human activities, it looks at stocks and flows of phosphorus across the food system (so the human activities creating some of those flows are implicit), and it wrestles with integrating knowledge from multiple systems and across multiple scales and levels. Consider the following quotation from a RePhoKUs interview:

> "We have phosphorus on the one hand, and on the other hand we have the food supply chain. Some of our focal levels are molecule, farm catchment, river basin, national – these levels themselves occur on different scales. This list is a mixture. This project involves physical, ecological, social, jurisdictional/legal scales, to name a few. There is also the food system scale, in terms of different types of actors involved in different food system activities. It's hard to define the boundaries of each of these levels, and how the scales and levels are situated with

respect to each other is complex. This has itself become a topic of discussion and research, and we have written a whole paper on this".

Table 3 Food System Activities and Food System Outcomes Included in or Excluded from GFS-FSR Projects (green is included; red is excluded)

Project	Food System Activities						Food System Outcomes			
	Production	Processing and Packaging	Distribution and Storage	Retail and Service	Consumption	Food Waste	Food Security	Nutritional Security	Environmental Outcomes	Socio-Economic Outcomes
BananEx										
FF&V										
I Know Food										
Pig Sustain										
RUGS										
Pollination										
SEEGSLIP										
Dairy										
ResULTs										
RePhoKUs										
T-Grains										
Diverseafood										
Rurban Revolution										

It would be an error to equate the level or amount of systemic practice with the largest number of food system activities included (as Ulrich, 1983, makes clear, being systemic does not mean being comprehensive – it is more specifically about justification for the boundaries in terms of impacts). All projects were limited by time and money, and the more food system activities and outcomes were included in a given project, the fewer dimensions of scope or resolution were included, indicating a clear trade-off.

The projects also differ greatly in their specification of 'outcomes'. Some projects define socio-economic outcomes in terms of the economic viability of farms, others in terms of "thriving communities" or "better food choices". Some projects see their relation to food security in terms of maintaining tonnage of supply, others in terms of maintaining the ecosystem services that underpin on-going food production into the future. The concept of 'outcomes' of the system in each of the projects is relative to its choice of purposes and values, which in turn directs the setting of a boundary around what is seen as being in the food system. What is not seen cannot be accounted for, thus creating a self-sealing logic of purposes, values and boundaries for each project. Outcomes are clearly relative to boundaries, as would be expected from the systems theory explained earlier (Ulrich, 1983; Midgley, 2000b). Different levels of abstraction exist when it comes to outcomes considered across the projects.

There is also a distinction between projects that focus on maintaining or improving an existing system architecture and its activities, and projects that seek to maintain and improve outcomes. For example, FF&V focuses on maintaining and improving the existing FF&V supply system, whereas the Pollination project is focused on maintaining pollination services as an outcome of food system activities. Likewise, RePhoKUs is concerned with systemic change in order to maintain or improve a range of ecosystem services, including clean water, biodiversity and the capacity to produce food. ResULTs has both concerns, in that it is focused on maintaining or improving upland sheep and beef farming where possible, but this is within the context of a broader focus on thriving upland communities and environments.

4.2 Synergies and Tensions

The differences between the various purposes, values and boundary judgements in the 13 projects has resulted in the generation of some seemingly contradictory recommendations for action as well as some mutually supportive calls for action, or synergies.

There is an obvious tension between the recommendation of the RUGS project that we reduce the consumption of animal products globally, and the recommendations coming from projects which are focused on maintaining and improving livestock and dairy production (ResULTs, SEEGSLIP, Dairy). There may also be a tension with Pollination because, in theory, a decrease in consumption of animal products could imply an increase in the demand for fruit and vegetables, and this would in turn increase the demand for animal (usually insect) pollination services. However, this has not been explored within the projects.

There are various potential synergies and trade-offs between the work and recommendations of the FF&V and Pollination projects. For example, both projects are working with farmers in East Anglia and there are potentially conflicting recommendations, in that the cropping patterns recommended in order to maximize pollination services are potentially more water intensive, and in turn some measures taken to improve water efficiency might negatively impact pollinators. There is also a potential synergy, in that pollination can partially compensate for some yield losses due to drought (Klein et al. 2015). However, it has not been possible for these two projects to explore the tensions and synergies due to pollination being excluded from the scope of the FF&V project.

In fact, Pollination is a great example to take, since there are potential synergies and tensions identified in relation to many other projects. There are large synergies between the RePhoKUs and Pollination projects, as many landscape management features that support the goals of RePhoKUs, support the goals of Pollination too. Hedges are an example of a landscape feature which have positive impacts on pollinator populations in the long term, pollination services in the short term, the amount of phosphorus leakage into ambient environments, and cultural values associated with the landscape (Garratt et al. 2017). There are potential synergies between Pollination and Rurban Revolution, given the growing evidence of urban green spaces supporting a surprisingly high diversity of pollinators, making the growing of fruit and vegetables much more viable, if these spaces are properly managed for this purpose (Baldock et al. 2015). There are synergies with SEEGSLIP, since many sustainable livestock practices, such as hay meadows, can support pollinator populations in the wider landscape and lead to increased pollination services. Pollination can inform PIGSUSTAIN, since the latter's findings may indicate a low level of pollination for field beans, a key pig feed crop in some areas. Finally, as potentially everything fits within I Know Food, the maps of pollinator dependence and pollination services generated by the Pollination project may give rise to on-farm tools to identify areas of strong or weak pollination, and this could help the planning of appropriate management strategies.

RePhoKUs has synergies with the livestock projects, since future P scarcity may affect livestock production, and management options to increase the resilience of P to scarcity will have knock on effects. Livestock density also drives phosphorus inputs into the food system, the phosphorus loading in potentially vulnerable catchment landscapes, and subsequent wastage and losses to water (Withers et al. 2019). Hence, livestock management options will have a large impact on phosphorus-related environmental outcomes. RePhoKUs also has synergies with Pollination from another side, because lower P inputs benefit soil and crop biodiversity, favouring pollinators.

There have been synergies between the research activities of I Know Food and the FF&V project, which both look at the supply chains of FF&V, and the projects have been able to share trade data and generate a joint report for DEFRA (presented at an officially sensitive EU Exit meeting at Oxford Martins School on 4th Dec 2018).

Researchers from I Know Food have written a piece on the Future of Farming with researchers from BananEx, with a focus on smallholders. This was written as a thought piece for the Fairtrade Foundation, to inform their new strategy document (not yet published). I Know Food also collaborates with SEEGSLIP on sharing best practices concerning farmer learning groups, and is coming together with PIGSUSTAIN on a new grant application.

Undoubtedly there are many more synergies and tensions between projects, and we encourage anyone reading this report who is aware of something not covered here to please flag this. It is beyond the scope of this short piece of work to do a complete systemic analysis of the synergies and tensions between the activities and recommendations of projects. Our purpose here is rather to show how reflections on system boundaries can facilitate the *identification* of synergies and tensions, by examining conflicting purposes or outcomes, and partially overlapping scopes in terms of both issues and stakeholders.

Any seemingly contradictory results from different programmes in fact highlight where tensions exist across sectors, scales, and levels within the broader system, and once they are identified, these tensions can be consciously managed. It turns out that applying multiple different lenses to 'the UK food system' provides valuable insights precisely concerning where tensions and synergies exist.

These tensions and synergies all have potentially important consequences for different groups of actors. They highlight how boundary judgements inevitably marginalise certain perspectives and give dominance to others, which can lead to the marginalization of the stakeholders who advocate those perspectives that are squeezed out. This can potentially include research team members within teams on projects, as well as external stakeholders. Of course, as we made clear in the earlier discussion of the systems theory underpinning our research, being all-inclusive is impossible. The issue is that the implications of decision making on boundaries need to be thought through, and this can be done by engaging in stakeholder dialogue and exploring what different boundary choices might entail – in terms of both the purposes and values being pursued, and the likely resource implications for the research. A lot of this exploration of necessity has to be done prior to the research being started, and this has implications for the funding of food system research: there is arguably the need for many small packages of funding for scoping studies, to do this exploration before large amounts of funding are allocated to the few most promising projects.

4.3 Boundary Dilemmas and How They Were Handled

Almost all the projects experienced some or all of the following:

1. Vagueness in the specification of what was included or excluded, requiring further refinement through investigation as part of the research process.

2. Differences of opinion about what or whom should be included or excluded within the scope of the project.
3. Changes or ongoing evolution of what or whom is included or excluded within the scope of the project, given changing understandings of the nature of the situation throughout the research process.

Different projects experienced these in positive or negative ways.

The overarching reaction to these experiences was positive, even if it was uncomfortable. Most saw tensions between competing frames as a learning opportunity. Consider the following two quotations:

> "We understand that this is a wicked problem and needs to be solved from all fronts. We understand that we are not covering it from all the fronts, but the more we cover it in the angles that we have, the better the solution. Boundary tensions are seen as a good thing and an opportunity for learning – something we hadn't thought of".

> "We have not had conflicts over boundary judgements. In fact, differences of opinion on this front have actually been one of the most interesting parts of the project. It has actually started really interesting conversations. What happened with our scales paper, something very similar happened with the stakeholder paper – it started out as a very normal stakeholder mapping process, but as it unfolded it turned out there really was a lot more to look at in terms of the interactions between different types of stakeholders, which in turn told us more about different types of systems, phosphorus, food and governance systems and the ways in which they are part of the other systems, and gave us different perspectives on who they are, what role they play in the situation and so on".

When resolving boundary dilemmas worked well, the mechanism for it was usually dialogical, and involved reference back to the original purpose of the project, often in terms of the desire for real world impact:

> "We see each other as sounding boards on whether the directions the work takes in each work package remains relevant to the overall objectives in terms of impact. We agree not to go into too much basic research and stick with applied research in all the work packages. Though we might not have the specific expertise in each other's areas, we do have the expertise in terms of what is relevant for solving the problem from an environmental and social perspective, so we ground the work back in the problem".

A minority of other projects had more negative experiences of differences of opinion about what should be included or excluded:

> "The project focused exclusively on the supply side and consciously turned a blind eye to anything that happens after the [product] has been supplied. Consumers and marginalized groups of actors involved in the supply chain were deliberately excluded, nutritional was excluded, everything outside of the industrial modality of supply, everything outside of a strict economic and technocratic rationality was excluded. … The enforcement of these system boundary judgements and the exclusion of issues of major concern to the researchers resulted in researchers feeling disenfranchised from the project. Some just did their own thing. There was difficulty mobilizing people to the same spot. Personality differences came into play. Alternative system boundary judgements were mocked. The undermining of others was part of the way in which the dominant system boundary judgements were enforced and interests were marginalized".

A way forward to deal proactively with this kind of problem was suggested by one interviewee:

> "There really is space for collective training on food systems thinking and how system boundary judgements work in order to provide safe environments for conversations to happen within projects. This could be a way to put more effort into developing a common language and understanding across the project. Not just academic language, because the way we each rally towards different ideas is shaped by our different values".

The way that boundary dilemmas were treated influenced the way they were resolved, which in turn influenced the impacts they had on the project teams and outcomes. In situations where boundary dilemmas were treated as an opportunity for learning, the method of resolving them was usually dialogue, during which mutual understanding and trust was built, and new insights gained. In cases where boundary dilemmas were treated as a threat to a dominant purpose and boundary judgement, the method of resolution could be authoritarian, and could be experienced as dismissive or hurtful. The result was increasing rigidity and closure of the dominant boundary, disenfranchisement of team members and a contraction of the number and range of research outputs produced.

Importantly, it was the projects that focused only on maintaining and improving an existing architecture or activity that were more likely to perceive boundary dilemmas as threats, and in general there were more conflicts within those projects than those focused on higher level outcomes. Programmes focused on outcomes displayed more flexibility and openness, not wanting to miss anything that could potentially support or hinder the higher-level outcome from occurring. There were no actual conflicts reported at all by participants in the outcome-focused projects.

A stated passion for real world impact made a difference to the way boundary dilemmas were handled. This makes sense in interdisciplinary teams, since different disciplines use different theories and methods, which relate to different boundary judgements, and if a single academic interest dominates, others can be marginalized. In contrast, in pursuit of real world impact, people are required to transcend their disciplinary boundaries (Thompson Klein et al. 2001), which is arguably one reason why transdisciplinary (and not just interdisciplinary) research approaches are enjoying a resurgence at the present time.

5 Discussion

5.1 Multiple Wholes

The overviews of scope of the GFS-FSR projects provided in Section 4.1.2 shows that there is not one single food system, but multiple ways of looking at what is going on in terms of food and in terms of systems. Within the literature on transformative collaboration, Kahane points out that all systems "consist of multiple wholes that are part of larger wholes. Arthur Koestler coined the term *holon* for something that is simultaneously a whole and a part" (Kahane 2017). He provides the illustration in Figure 8.

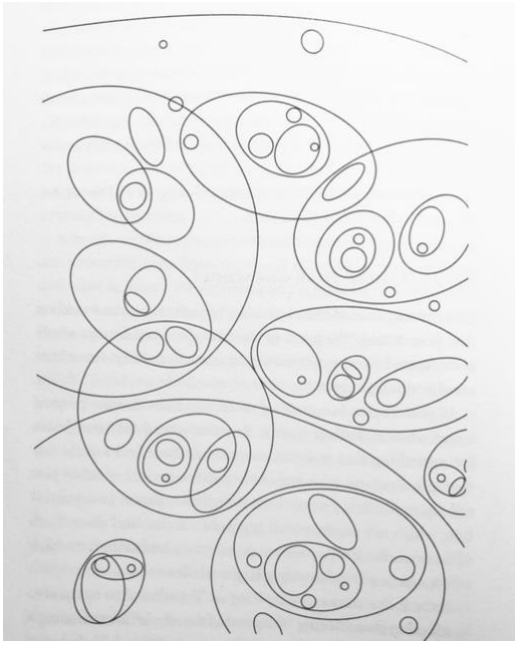

Figure 8 Holonic Structure of Systems (Kahane, 2017)

Accordingly, he says, when people "claim to be focusing on "the good of the whole" it really means "the good of the whole that matters most to me"".

Kahane gives an organizational analogy: if we say we are prioritizing ""the good of the team"…., then by implication we are deprioritizing the good of individual members of the team (smaller wholes) and of the whole organization (a larger whole)". Indeed, it is usually only the team manager whose interests coincide with that particular whole. There is a lesson here in analysing the GFS-FSR research programme.

The ResULTs project, focused on Upland areas of the UK, has a smaller scope than the RUGS project, which is global. Globally, there is a clear need to manage and reduce consumption of animal products. In light of the point made above, consider this quotation from a ResULTs project interview:

> "This project isn't just about food security in terms of tonnage/how much sheep and beef make it into the supply chain, the project is about *the upland areas themselves*. Upland areas supply relatively little of the sheep and beef in the food system, *but these areas, people, communities and environments matter*. What would happen to the uplands if we got rid of sheep and beef?"

Those "*areas, people, communities and environments"* are not included at the level of resolution used by the RUGS project. So, while it is true that, globally, the consumption of animal products needs to be managed, there remains an ethical dimension to how the interests of different wholes are managed (in this case a sub-system). Whichever whole we attend to, whether it is a larger or a smaller one, we are potentially marginalizing certain people or concerns, and there is no 'whole' that includes everything. It is therefore imperative that "we therefore attend not simply to the good of a single whole, but rather to the good of multiple nested and overlapping holons and to the richness and conflict this inevitably reveals" (Kahane 2017).

5.2 The Role of Reflection on System Boundary Judgements within Food Systems Research

The process of undertaking this research has revealed that reflection on the boundaries of food system constructs helps to identify the sources of selectivity that condition a claim, by surfacing the underpinning value and boundary judgments made. For example, the FF&V project focused on the resilience of the supply system in terms of tonnage and price. Claims that the FF&V supply system is

"relatively resilient at the moment" rely on including only tonnage and financial viability in the measures of success, and excluding other issues that might matter, including the mental health of farmers, the labour conditions of farm workers, the nutritional content of supply, or any of the other conscious exclusions listed in Table 2.

Systems theorists are very clear that being systemic is not about being comprehensive; it is about dealing with the inevitable *lack* of comprehensiveness by exploring different possible boundary and value judgements (Ulrich, 1983; Midgley, 2000b). So, research projects cannot do everything, but it is important to be clear about the sources of selectivity that condition a claim, since the results of these research projects will hopefully influence policy and action. That boundary judgements are inevitable does not mean that they can be arbitrary and without ethical or practical consequences. Examining boundary judgements in this way helps to reveal their practical and ethical implications, and what difference they make to the way we, and those we communicate with, see the situation in question.

Reflecting on system boundary judgements *across* projects is also extremely helpful. By giving alternative answers to some of the boundary questions, the different projects help identify the reference system that conditions the claims made by each project. For only in the light of alternative reference systems can we fully appreciate the selectivity of the one we are immersed in (Churchman, 1968b). This is strongly illustrated by the example of RUGS and ResULTS in Section 5.1.

Further, reflection on boundary judgements across projects transforms recommendations that may seem potentially contradictory into systemic insights about synergies, and also trade-offs that need to be managed, as illustrated in Section 4.2. The process of comparing projects and their boundary judgements teaches the value of a sort of pluralism where what can be learned from tensions across frames is appreciated. In fact, in the future, a deliberate strategy of diversity could be employed to ensure the broadest possible coverage of perspectives across a programme. There are current biases towards production and supply lenses, rather than consumption driven lenses. Nutrition and health are light in the programme, and waste (other than phosphorus in waste water) is not really touched upon at all.

The light touch process used here also highlights how, in the future, a project where boundary reflection is applied together with stakeholders, can assist in the creation of mutual understanding with regards to their different reference frames (think, for example, about the reference frames of vegans compared to upland sheep and beef farmers, or the reference frames of environmental policy makers compared with those used by a phosphorus researcher or a fertilizer manufacturer). If, in the process, a shared notion of the relevant reference system can be achieved, so much the better; but even if no agreement can be reached, understanding the way reference systems differ still represents an important gain in communicative rationality (Checkland and Scholes 1990; Gregory and Romm 2001; Checkland and Poulter 2006). Misunderstandings can be avoided or overcome in this way, and mutual tolerance can grow, and that in itself is an intervention which increases systemic resilience, as highlighted by the very purposes of the I Know Food and T-Grains projects.

Finally, when some of the parties in projects handle their own boundary judgments uncritically, either because they take them for granted or try to impose them on others, it may become necessary to use the legitimate platform of programme leadership to support the parties in boundary reflection. This can be framed as a constructive learning opportunity (as identified by many of the participants in this research), and need not involve 'singling out' any particular team members if it becomes routine that projects discuss boundary dilemmas in wider programme meetings. This is both an ethical and a practical necessity since, as can be seen from the various GFS-FSR projects, all boundary judgements are based on the purposes and values of the people making them, and they have practical, real-world implications for people whose lives will be affected by the interventions being proposed. There are no

absolutely ‘right’ and ‘wrong’ boundary judgements. It’s just that each boundary judgement relates to a particular purpose, motivation, values, worldview and framing, and each boundary judgement has ethical and practical consequences for different groups. So dialogue on different possible boundaries is required, together with explorations of their likely practical consequences (Flood and Ulrich 1990).

We should not rest on unjustifiable claims of unachievable comprehensiveness, or even objectivity, as all scientific observations take place after a prior values-based judgement on what to observe, whether this is explicitly recognised or remains implicit (Midgley, 2003, 2008). The decision on what boundary and value judgements should underpin the research, and ultimately guide practical action in response to findings and recommendations, is therefore a question of legitimacy rather than validity – and this is perhaps one of the most important insights from a systems approach. What reflection on boundary judgements does is help the parties to appreciate their own boundary assumptions and those of others, so that conversations can be transparent and productive and an ongoing process of learning and adaptation can be enabled, both within and across research projects.

As one of the interviewees from I Know Food said, when providing feedback on our research process, reflection on system boundaries “helped us to see how our project fit into wider food system debates”.

6 Appendix A: Ulrich's 12 Critical Systems Heuristics Questions

SOURCES OF MOTIVATION

1. Who is (ought to be) the **client** or beneficiary? That is, whose interests are (should be) served?
2. What is (ought to be) the **purpose**? That is, what are (should be) the consequences?
3. What is (ought to be) the **measure of improvement** or measure of success? That is, how can (should) we determine that the consequences, taken together, constitute an improvement?

SOURCES OF POWER

4. Who is (ought to be) the **decision-maker**? That is, who is (should be) in a position to change the measure of improvement?
5. What **resources** and other conditions of success are (ought to be) controlled by the decision-maker? That is, what conditions of success can (should) those involved control?
6. What conditions of success are (ought to be) part of the **decision environment**? That is, what conditions can (should) the decision-maker *not* control (e.g. from the viewpoint of those not involved)?

SOURCES OF KNOWLEDGE

7. Who is (ought to be) considered a **professional** or further **expert**? That is, who is (should be) involved as competent provider of experience and expertise?
8. What kind **expertise** is (ought to be) consulted? That is, what counts (should count) as relevant knowledge?
9. What or who is (ought to be) assumed to be the **guarantor** of success? That is, where do (should) those involved seek some guarantee that improvement will be achieved – for example, consensus among experts, the involvement of stakeholders, the experience and intuition of those involved, political support?

SOURCES OF LEGITIMATION

10. Who is (ought to be) **witness** to the interests of those affected but not involved? That is, who is (should be) treated as a legitimate stakeholder, and who argues (should argue) the case of those stakeholders who cannot speak for themselves, including future generations and non-human nature?
11. What secures (ought to secure) the **emancipation** of those affected from the premises and promises of those involved? That is, where does (should) legitimacy lie?
12. What **worldview** is (ought to be) determining? That is, what different visions of 'improvement' are (should be) considered, and how are they (should they be) reconciled**?**

7 Appendix B: GFS Workshop Handout

Questions	Personal Answers	Comments by Others
Inclusions. What economic, social, political and environmental issues (and their interactions) are you researching?		
Exclusions. What economic, social, political and environmental issues have you deliberately excluded? I.e., the issue(s) have occurred to someone in the team or a stakeholder as being relevant, but you have set them aside or feel they present a dilemma.		
Incoming Impacts. What issues that you are *not* currently researching impact on the issues you *are* researching?		
Positive Outgoing Impacts. If your project achieves the change you desire, what *positive* knock-on effects might this have on other issues and stakeholders?		
Negative Outgoing Impacts. If your project achieves the change you desire, what *negative* knock-on effects might this have on other issues and stakeholders?		
Included Stakeholders. Who is centrally involved in your research? I.e., partners, or helping to shape the research. Name people and agencies and say why they are important.		

Excluded Stakeholders. Is there any stakeholder (person or agency) who could have been relevant, but you have deliberately chosen not to involve? Why?		
The Affected. Who are the stakeholders who could be *affected* by your project but are not centrally involved?		
What Matters to the Affected. What issues are those affected stakeholders concerned with, and what does this say about what you might have deliberately or accidentally excluded?		
Different Perspectives. Can you think of people with very different perspective(s) from the team and the involved stakeholders? If so, what would they be asking you to include that you are not currently?		
Values and Ethics. What priority values (what matters to you) and ethics (ideas about what ought to be done) have informed your choices of stakeholders and issues?		
Marginalized Values and Ethics. Are there potentially relevant values and ethics that are not currently prioritised, which (if you made them central) would change who you are working with or what you are researching?		

8 Appendix C: Semi-structured interview guide

Part 1: Begin by introducing the boundaries project, it's motivation, context, purpose and objectives.

If the interviewee was in the workshop activity, ask if they would like further information on what boundary judgements are and why they matter, and begin by reviewing the answers provided on the handout.

If the interviewee was not in the workshop activity, briefly explain what boundary judgements are and why they matter, since the interviewee will not have heard this explanation before.

Part 2: Ask the interviewee to describe the purpose of their project, and their personal motivation in their own words.

Part 3: Explore any moments they can recall, in which certain issues, values, ethics, or stakeholders were excluded (or included) from the scope of the project, and ask them to talk these through (were they dilemmas or decisions?). Discuss how these inclusions of exclusions have made a difference to the project.

Part 4: Reflect on any disagreements within the team regarding the framing of issues or the inclusion or exclusion of anything from the project What impacts has they had?

Part 5: Explore whether or not they have had to carefully manage any stakeholder relationships. What was the reason for this and what impacts did this have?

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