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Article

Scoping Potential Routes to UK Civil Unrest via the Food System: Results of a Structured Expert Elicitation

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Abstract: We report the results of a structured expert elicitation to identify the most likely types of potential food system disruption scenarios for the UK, focusing on routes to civil unrest. We take a backcasting approach by defining as an end-point a societal event in which 1 in 2000 people have been injured in the UK, which 40% of experts rated as "Possible (20–50%)", "More likely than not (50–80%)" or "Very likely (>80%)" over the coming decade. Over a timeframe of 50 years, this increased to 80% of experts. The experts considered two food system scenarios and ranked their plausibility of contributing to the given societal scenario. For a timescale of 10 years, the majority identified a food distribution problem as the most likely. Over a timescale of 50 years, the experts were more evenly split between the two scenarios, but over half thought the most likely route to civil unrest would be a lack of total food in the UK. However, the experts stressed that the various causes of food system disruption are interconnected and can create cascading risks, highlighting the importance of a systems approach. We encourage food system stakeholders to use these results in their risk planning and recommend future work to support prevention, preparedness, response and recovery planning.

Keywords: food systems; global catastrophic risk; climate change; extreme weather; ecological collapse; scenarios; cascading risks

1. Introduction

There is growing public, political and academic awareness of the risk of global catastrophes [1–6]. These are sudden, extraordinary, widespread disasters that possess one or more of the following properties:

- Beyond the collective capability of governments and the private sector to control [7];
- Cause significant harm at the global scale, such as a large reduction in global population [8];
- Precipitate the failure of critical global systems, including the cluster of socio-technological systems sometimes called "human civilisation" [9].

While there are many kinds of global catastrophe and the risk of one occurring is driven by numerous processes, food insecurity has been identified as both a cause and consequence of many catastrophe scenarios [10].

The food system has been highly optimised for efficiency, sometimes with little or no redundancy at individual nodes, and with a high degree of temporal coordination ("just-in-time" delivery). The vulnerability of the food system has been pointed out by multiple experts over the past few years (e.g., [11–13]) and was laid bare for all to see during the COVID-19 pandemic [14,15]. Meanwhile, we are experiencing an increasing number of extreme weather events impacting food production, many driven by climate change, and have seen that different disruptors can compound each other to disrupt supply (e.g., Brexit and COVID-19 [11]). Looking ahead to the coming decades, it is entirely possible that extreme weather will cause major crop yield failures across multiple breadbaskets (food production regions), as extreme weather is becoming more correlated across hemispheres [16,17].

The impact on food supply in a particular country or region could be significantly compounded by ensuing disruptions to global trade (e.g., protectionism), or by other events such as pandemics, volcanic ash clouds, land degradation, extreme weather events, wars or local disruptions to key "chokepoints" in global food supply chains [18]. This serious threat to food production has the potential to lead to civil unrest [19]. For example, the 2010 Russian heatwave-driven wheat shortage drove up international prices that contributed to disorder in Mozambique and played a role in the Arab Spring [20]. The meteorological cause of this extreme event was a strongly meandering summertime jet stream [21] which, due to its capacity to drive teleconnections between regions, has the potential for even greater impacts on food security through synchronous breadbasket failures [22,23]. Similar shocks to food production, which have impacted global prices, have been seen in Australia, China, Canada, India, USA, Ukraine and Argentina [24] over the past 40 years. While the likelihood of these and other hazards is difficult to calculate, it is not zero, and their impact is potentially catastrophic.

Previous food crises have led to changes in policy, including changes to agricultural management practices, expanded industrial farming and productivity, as well as international trade [25]. More recent events (over the past century) have seen global food prices triple (or more) over weeks or months, resulting in access issues around the world due to cost.

While the number of regions prone to famine has reduced over time [26], the current food system is increasingly challenged by a different set of dynamics that creates food insecurity—namely, global food supply chain risks and affordability issues driven by loss of income and volatility in food prices [25]. For example, the total amount of food might be relatively unaffected by a crisis, but there could suddenly be major challenges in distributing food caused by a breakdown in financial systems, trade restrictions, transportation failures or disruptions to the internet or electricity supply systems. These could be triggered by a mass computer virus attack [27] or a large release of plasma from the surface of the Sun (coronal mass ejection) disrupting electricity grids and communications [28]. Short-term impacts on food supply can include a shortage of transport fuel [29], strikes and protests [30] or major flooding across the road infrastructure [31].

Within a single country, such disruption to food access can be caused by an overall reduction in food supply or uneven food distribution. In this work, we choose to focus on a single country—the United Kingdom—although many of the issues will be relevant in other geographies.

Currently, just under 50% of the UK food supply is imported [32]. Food is brought into the UK in boats, aeroplanes and trains (with around 85% coming via boat). However, 98% of all UK food is transported by road once it is in the UK [33]. Over 80% of UK fruit is imported, as is almost 50% of UK vegetables, whereas the UK is almost completely self-sufficient for wheat, barley, lamb and potatoes, and only 20% of beef and poultry is imported [33]. Fewer than 15% of calories in the UK food supply come from fruit and vegetables, which is a relatively small fraction [34].

Residents of the UK lived through a short-term food distribution problem that built up over, and lasted for, a period of weeks through the start of the COVID-19 pandemic in 2020 [35]. Although the food system was considered an essential service and, therefore, exempt from most lockdown restrictions, the restrictions on the movement of people disrupted the supply chain globally [15], and social distancing measures were a challenge on many packaging lines. Furthermore, consumption patterns and sourcing changed markedly as people worked from home instead of using catering outlets [36], with production processes proving difficult to change to meet this new demand over short timescales. This was compounded by citizens both panic-buying and prudently stockpiling in case of illness and potential longer-term disruption [37]. This led to empty supermarket shelves, even though the total amount of food in the UK was sufficient to meet immediate needs. Flour was a key example of this in the UK, where most mills were set up to supply bakeries and wholesalers with flour in tankers or in large sacks (typically 16 kg). Millers could not pack it into small, retail-sized 1.5 kg bags quickly enough to satisfy increased retail demand. This was largely resolved in the UK over a period of weeks, as the peak of the pandemic passed and citizens reached an equilibrium in their food-purchasing patterns.

Brexit has also caused major short-term disruptions to the UK's food supply chain, including challenges and delays with imports (and exports), uncertainty over regulation and challenges with harvests, due to the reliance of parts of UK agriculture on seasonal migrant workers [38].

In the winter of 2022, the cost-of-living crisis, combined with cold weather, rendered the amount of money available for food too low for many people. For example, The Food Foundation reported that a quarter of households with children experienced food insecurity in the month of September 2022 [39]. The number of three-day emergency food parcels handed out by the Trussell Trust in 2021/22 was 2.2 million, a tenfold increase from 10 years earlier, with 25% of the people who used food banks in August 2022 having never previously done so [40].

COVID-19, Brexit and the cost-of-living crisis show that the UK food system is already exposed to certain risks. In this paper, we speculate that there is a range of types of risks to the UK food system that can be populated from studying Global Catastrophic Risks (GCRs) and that, by mapping out these risk types, we can provide an efficient way to prepare for both GCRs and other threats to the UK food system, some of which may be unknown at this stage.

In this work, we aim to assist with preparations to avoid UK-food-system catastrophe by eliciting the opinions of food system experts on the probability of problems and their likely causes. This will help with prioritisation of efforts to mitigate against a catastrophe occurring in the first place and with the development of emergency response plans to be deployed in the event of a catastrophe, to reduce the societal impact. We emphasise that the results of this work are not predictions of what will happen to the UK food system, but rather an indication of the range of potential outcomes based on the expert opinions given and the food system events, scenarios and drivers considered.

2. Methods

This paper draws on primary (online survey) and secondary qualitative (from the literature) and quantitative (from literature and online data repositories) data sources to develop a plausible scenario of a UK-food-system shock over the next 10–50 years. We adopted structured expert elicitation [41] to inform potential outcomes and causes of a food system shock. There have been a number of attempts to estimate the likelihood of complex system disruptions or specific kinds of global catastrophe, using a variety of methods; however, this remains a challenging and nascent field. Given the significant degree of uncertainty and the lack of data available to make probabilistic assessments of the likelihood of such events, expert elicitation methods have been found to be well suited to this research [42]. In addition, the need to combine information and perspectives from many disciplines necessitates the adoption of a structured approach to gathering the data. Therefore, structured expert elicitation was adopted as a method.

In our pre-elicitation phase, the literature and data from past events were used to inform potential future impacts and an initial conceptual model of plausible risks to the UK (see Question 3 in Appendix A for the list of causal risks included in the conceptual model). We used these data to underpin a set of scenarios over multiple time horizons. We note that this list of plausible risks is not exhaustive and some risks overlap. However, this initial list allowed experts to consider the broad trends potentially contained within the scenarios.

A pilot phase with a group of 10 experts drawn from academia, industry, non-governmental organisations and government was used to gather initial responses to refine and update the scenario outlines, conceptual model and survey structure.

A set of 76 food system experts were then invited to complete an online survey through direct approach [43] and snowball sampling [44,45], as recommended in qualitative sociological studies when access to specialist judgement and assessment is required. The experts chosen were predominantly those with food systems backgrounds, but efforts were made to ensure a wider range of domains were covered.

Within structured expert elicitation, the number of experts chosen varies, depending on the depth and range of expertise required, with some researchers opting for 5 experts [46] and others recommending up to 20 [47]. However, for our study, as no single expert could cover the whole range of risks we explored, we opted for a larger number of well-informed experts, to cover different academic disciplines, as well as for approaching a number of practitioners. The academic expertise included policy, biodiversity, climate science, agriculture, primary production, supply chains, land use, modelling, nutrition, consumption and waste. Practitioner expertise was sought from government departments, think tanks, farming, insurance, retail, charities and non-departmental government agencies.

We acknowledge that some bias may still exist within the data collected, as the experts were all drawn from within the UK and it is not possible to ensure that expertise on all possible future risks was covered by those who completed the questionnaire, although this was mitigated to some extent through the large number of experts approached. In addition, further risks were able to be added by the experts in a free-text box in the survey and, therefore, the risks were not restricted to those identified in the initial conceptual framework. We also acknowledge that the timing of such an expert elicitation may introduce bias that impacted the risks considered and likelihood measures agreed, especially with global events such as COVID-19 and the war in Ukraine potentially increasing the perception of related risks. The experts filled in the survey during the period April–June 2023.

In total, 58 experts (including the initial group and further experts) from a wide range of sectors (see Figure 1) completed the survey. We refer to these as the participants hereafter. Roughly one third of the participants have first names traditionally given to women and two thirds to men. All participants in the survey were then invited during post-elicitation to review the data collected and add commentary through the formal process of co-authoring this paper.

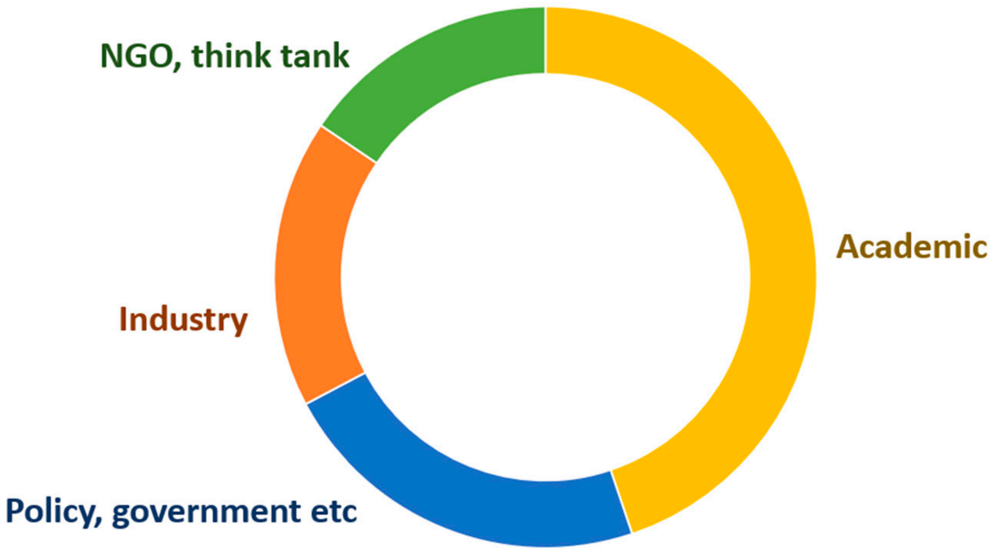

Figure 1. Classification of the employment types of the survey participants.

We designed a set of six multiple-choice questions, taking a backcasting approach [48]. We asked participants to answer all 6 questions for a 10-year timeframe, and then repeated the questions for a 50-year timeframe. The first question concerned the likelihood of civil unrest, which was followed up with a question about which of two broad types of food system disruption might have caused this unrest. For each type of food system disruption, the survey then asked the likely cause and the commodities that might be affected. The set of survey questions is included in Appendix A, and each question is described in more detail below.

Societal Event

In this paper, we are interested in the ultimate impact of food system shocks on society, for example, through potential breakdown of law and order and fear for personal safety. We start by defining a societal event containing a level of potential civil unrest (Box 1). Previous work has used a definition of food riots which includes "*violent, collective unrest leading to a loss of control, bodily harm or damage to property, essentially motivated by a lack of food availability, accessibility or affordability, as reported by the international and local media, and which may include other underlying causes of discontent*" [49,50] and has used newspaper article keyword searches and the food riot database from the Food Price Crisis Observatory from the World Bank [51]. Civil unrest is defined in terms of societal safety, conflict and militarisation [52] and includes the risk of significant social unrest as well as the risk of disruption to business [53].

Box 1. The Societal Event considered in this work.

Societal Event "Civil unrest has occurred in the UK, as defined by violent injury of more than 30,000 people in one year, due to e.g. violent looting, strikes, demonstrations, or crime including hate crime (i.e., roughly one in 2000 people are injured, which is 10 times greater than the number of injuries in London riots in 2011)."

We adopt a measure of civil unrest that specifies the rate of involvement of the population, which would enable potential future categorisation according to impact (number of people affected) and scale (geographical spread). During past events, the number of deaths in civil unrest is still relatively low compared to the background level of violent crime, which makes statistical significance challenging. The number of arrests is well quantified, but may depend on the judicial regime in the specific country or region and would not scale linearly with the level of unrest in the event of a breakdown of law and order. For illustration and definiteness in this work, we describe the level of future potential civil unrest in terms of the number of people injured.

To put numbers into perspective relevant to the participants, we considered the English riots in 2011, which took place over five days in August, mostly in London, Manchester and the West Midlands, following the death of a black man shot by the police. The riots are estimated to have involved 13,000 to 15,000 active participants, with 4105 arrests and 5175 crimes recorded, including 1860 incidents of arson and criminal damage, 366 incidents of violence against the person and 5 fatalities [54,55]. The definition of "violence against the person" includes murder, wounding, grievous bodily harm, assault and possession of weapons, and it made up 7% of all the recorded crimes, of which there is some overlap with the 13% of crimes which were classified as targeted at individuals, typically robberies or assaults [54].

To account for the fact that the majority of England did not experience the riots, we focus on London, where the majority of the crimes occurred. Specifically, the region administered by the Metropolitan Police, in which there were 3461 crimes, of which 7% (242) were crimes of violence against a person [54], in line with the whole-of-England rate. We estimate 450 crimes were targeted at individuals (13% of the 3461 crimes).

Using the 32 London Boroughs policed by the London Metropolitan Police, a total of 242 crimes of violence corresponds to approximately 1 in 30,000 people (using a population of just over 8 million in those boroughs [56]). With 450 crimes targeted at individuals, 1 in 18,000 people would be impacted. For our scenarios, we chose a rate 10 times greater than this which, with a projected UK population of 70 million, translates into approximately 40,000 crimes targeted at individuals or approximately 20,000 incidents of violence against a person. Therefore, we state 30,000 injured to set the scene in our scenarios (Box 1). We note here that these measures represent reported crimes and, therefore, the true figures of injuries are likely to be higher. As a further comparison, more recently, approximately 1 in 20,000 people in France were arrested during the riots in late June to early July 2023

(3400 people arrested over 5 nights within a population of 68 million [57]) following the shooting of an unarmed teenager by police.

To help mitigate or prepare for civil unrest being caused by the food system, we asked participants whether, if the unrest had occurred, it would have been more likely to have been caused by (i) insufficient food available in the UK or (ii) a problem with food distribution, despite adequate total calories being available in the UK (Box 2).

Box 2. The two Food System Scenarios considered in this work.

Food System Scenario 1: Insufficient UK Food
"There are now insufficient calories available to feed the UK population, and this has contributed to the Societal Event"
Food System Scenario 2: Food distribution problem
"There is a food distribution problem leading to geographically isolated pockets of hunger, despite adequate total calories being available to feed the UK population, and this has contributed to the Societal Event"

We then extend the backcasting approach to ask how each Food System Scenario might have arisen. We provide multiple-choice options based on the list of drivers from our initial conceptual model of plausible UK catastrophic risks, and invited participants to choose up to three as the most likely cause of the food system scenario, noting that the causes might have occurred individually or in combination. It was not possible for participants to select one option multiple times, but it was possible for them to choose more than three options—however only one participant did this in practice. When reporting on the percentage of responses, we divide by the number of participants for clarity (rather than the number of total responses).

The final set of questions aimed to highlight which parts of the food system might be most critical in precipitating civil unrest via the food system scenarios. Participants were given the choice between five types of food commodity and asked to select up to two which they thought would be most likely to lead to civil unrest through the relevant scenario. Two of the options were overlapping but were distinguished between (i) popular carbohydrates such as wheat, bread, pasta and cereal and (ii) most carbohydrates, including oats, potatoes and barley. The purpose of this was to distinguish between an apparent food shortage (lack of popular carbohydrates) and a calorific food shortage in which no major staples could fill the carbohydrate gap.

3. Results

We asked participants to give their opinion on the plausibility of civil unrest as defined by our scenario occurring in the next 10 years (left panel of Figure 1) and found that 45% considered this "Unlikely (5–20%)", while 14% of participants thought this would be "Very unlikely (<5%)". However, 38% rated this "Possible (20–50%)" and 3% rated it as "More likely than not (50–80%)". When asked about the plausibility of the same level of unrest occurring over the next 50 years (right panel of Figure 2), by far the most popular answer was "Possible (20–50%)" which corresponded to 45% of responses, followed by nearly one quarter of respondents replying "More likely than not (50–80%)" and 10% saying "Very likely (>80%)".

Overall, we see the majority of participants answering that there is a greater than 5% chance of serious civil unrest over the next 10–50 years, with an increase in plausibility, as expected, for the 50-year timeframe, for which the majority of responses estimate more than 20% chance of such civil unrest.

On a 10-year timeframe, we see that the majority (over 80% of respondents) consider it most likely that a food distribution problem would be the cause of civil unrest, rather than a problem with the total amount of calories available in the UK (left panel of Figure 3). Conversely, on a 50-year timeframe, the conclusion is reversed, with 57% of participants predicting that a civil unrest event (if it occurred) would be due to insufficient food being available in the UK (right panel of Figure 3).

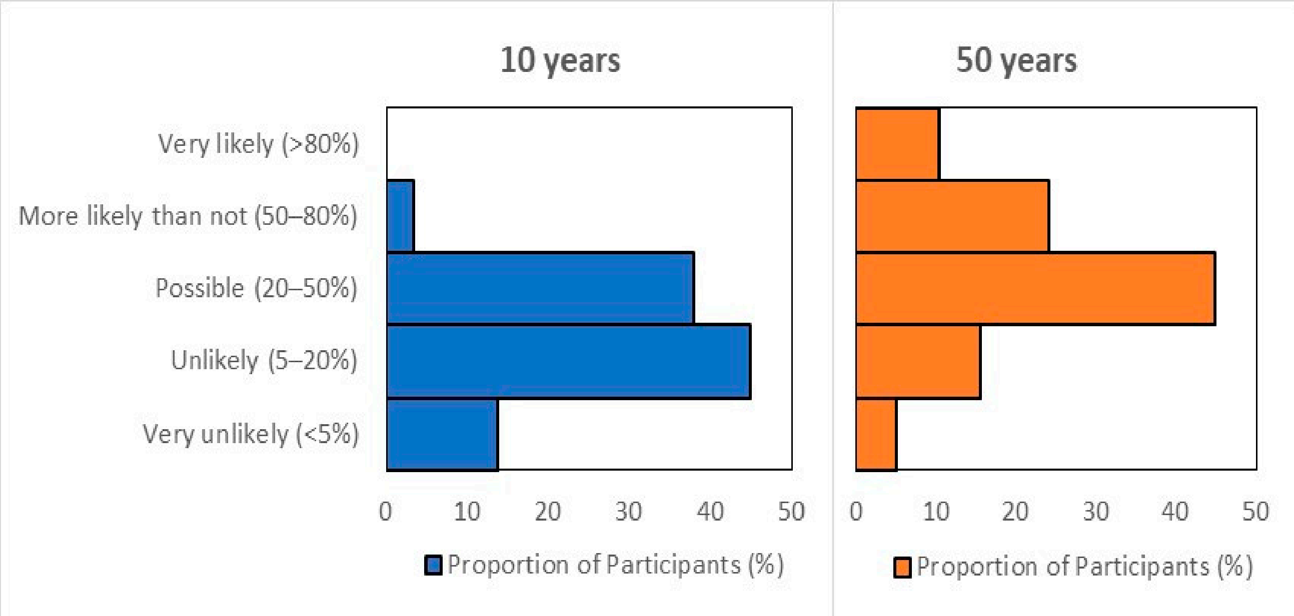

Figure 2. Plausibility of the Societal Event as a function of time. Results of "In your opinion, how plausible is this Societal Event to occur in the next 10 years?" (**left**) and "In your opinion, how plausible is this Societal Event to occur in the next 50 years?" (**right**).

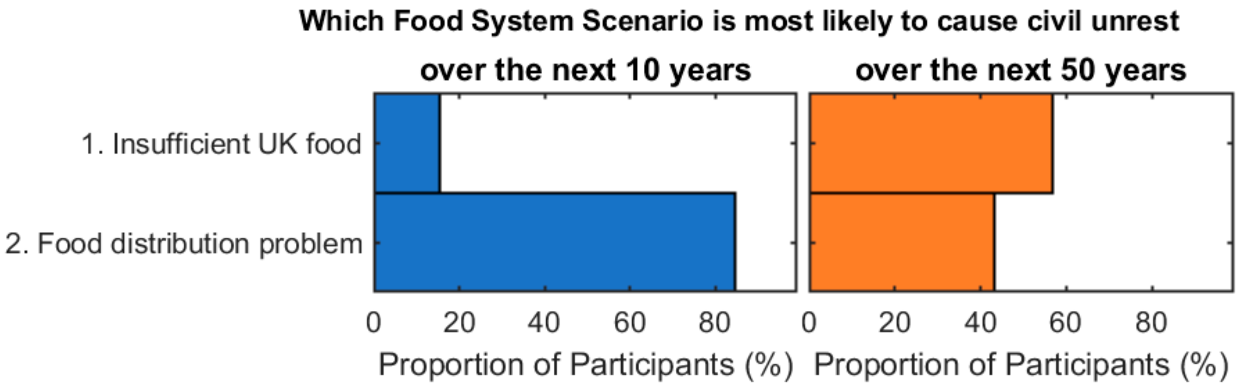

Figure 3. Results on which Food System Scenario is most likely to have caused civil unrest if it occurs in the next 10 years (**left**) or next 50 years (**right**).

3.1. Causal Pathways Leading to Different Food System Scenarios

"Extreme weather (including storm surges, flooding, snow, drought)" was the most common response across both scenarios and both timescales, with over two thirds of participants choosing it in every case (Figure 4). Over 85% of participants chose this option as the cause of insufficient UK food over 50 years. We note that extreme weather disruption can apply to both domestic production as well as imports, although no separation was made in the categorisation in relation to this.

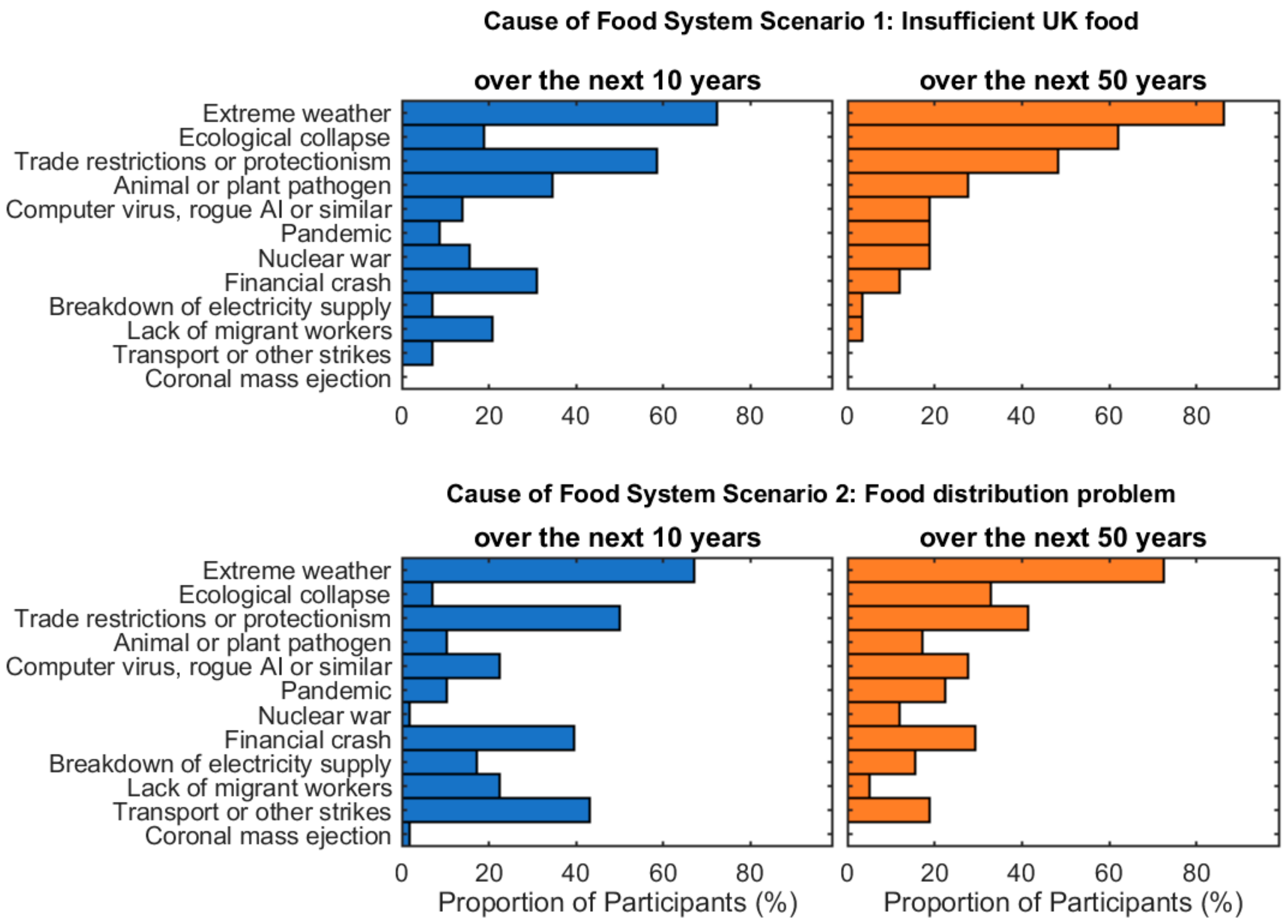

Figure 4. Results of asking participants about the causes of Food System Scenario 1 (insufficient UK food, **upper panels**) and Food System Scenario 2 (food distribution problem, **lower panels**) for each of the two timeframes of 10 years (**left panels**) and 50 years (**right panels**).

For Scenario 1 (insufficient UK food), the next most popular cause was 'trade restrictions or protectionism', which was also a common response for the 50-year timeframe. This likely reflects the relatively high import rate of UK food and the risk of this being curtailed in the event of geopolitical instability or other international food scares (e.g., see [51]). On the 10-year timeframe, about a quarter of participants also cited "animal or plant pathogen" and "financial crash" as being likely causes in the event of insufficient UK food. The fraction of participants selecting ecological collapse as the cause of insufficient food over the next 10 years was around 20%, but this rose to over 60% for the 50-year timeframe.

For Food System Scenario 2 (food distribution problem), in the 10-year timeframe, 40–50% of participants selected "trade restrictions or protectionism", "transport or other strikes" and "financial crash", in addition to the 67% who selected "extreme weather". Around 20% chose "lack of migrant workers", "breakdown of electricity supply" and "computer virus, rogue AI or similar". It was perhaps surprising that only around 10% of participants chose "pandemic", despite the disruption that arose during COVID-19, perhaps because of the adaptations that already occurred in the food system as a result of the pandemic, for example, product consolidation and legislation responses to modified labelling. Over the 50-year timeframe, 9 of the causes were selected by around (or more than) 20% of participants, with "ecological collapse", "animal or plant pathogen" and "pandemic" becoming important relative to the 10-year timeframe.

"Coronal mass ejection" was not selected by a significant fraction of participants for any scenario or timeframe. "Nuclear war" was not selected by more than 20% of participants for any timeframe; however, 15–20% of participants considered it a potential top-3 cause of insufficient UK food for both timeframes, and over 10% considered it a top-3 cause of a food distribution problem over 50 years.

The survey provided space for participants to list other potential causes, beyond those provided in the multiple-choice list. Within the 10-year timeframe, several participants highlighted food contamination events (biological, natural chemical or artificial chemical) as a particular concern. Such events have immediate impacts on food availability but also can create wider indirect impacts across the food system. For example, previous food contamination events—such as diesel fuel in Spanish olive oil, melamine in Chinese milk powders or *Escherichia coli* in organic bean sprouts—created direct health impacts on consumers and, alongside other contamination events such as horse meat in meat supplies, lowered trust between consumers and food suppliers [58].

For Scenario 2, an additional cause mentioned by a few participants was a potential breakdown in cooperation within society. This could be a result of devolution leading to partisanship between regions, political instability or extreme fascist politics. A non-nuclear (European) war was highlighted as a potential cause of wider disruption. The potential for large agricultural producers (such as China, Russia and the US) to use trade as a warfare tool was also suggested by one participant.

Over a 50-year timeframe, many participants highlighted similar issues to the 10-year timeframe, although ecological degradation (as opposed to ecological collapse)—including soil depletion, insect populations and water storage—was added as a key area of concern. However, both ecological collapse and degradation were seen as regionally specific, although, if located in areas of high significance for food production, they can have a significant impact.

Several participants highlighted causes arising from wider societal risks, including endemic poverty, increased population (through immigration) and an ageing population. Consumer responses during food system catastrophes such as panic-buying or hoarding can also act as a feedback response on the scale of impact. In addition, an increase in the costs of farming inputs (energy, feed, labour), difficulty in securing labour, a move to use land to service carbon or biodiversity markets or the impacts of trade deals that undermine domestic production could see a reduction in UK domestic production as farmers leave the industry.

Finally, several participants highlighted that a single causation acting as a trigger by itself is less likely than a number of the causes acting in an interconnected, as well as cascading (one cause can then trigger another), way. Therefore, scenarios can be compounding. An extreme weather event, for example, could lead to ecological collapse or impact transport infrastructure, and the likely pathway to catastrophe will include feedback between events, with unrest building up over time. As one participant highlighted "*something happens, markets panic, governments panic, debt/inflation goes up, geopolitical tensions ramp up then when the next thing happens everything is more jittery*".

3.2. Developing Expanded Food System Scenarios

In both scenarios and both timeframes, the most commonly selected option was "popular carbohydrates (wheat/bread/pasta/cereal)", with around 60% of participants choosing this option (Figure 5). The second most commonly selected option was "fruit and vegetables", chosen by close to 50% of participants. In most cases, "dairy or eggs" was the commodity of least concern, followed by "meat or fish".

On the 10-year timeframe, there was a marked difference between food system scenarios on shortage of "meat or fish", with more concern around there being a food distribution problem for meat or fish as compared to insufficient total UK meat or fish.

Within the free-text comments, several participants highlighted a concern in both the 10- and 50-year timeframe around the availability of clean water. As a key input to the food system, any shortages of water (whether absolute or seasonal) will have a significant impact on food production.

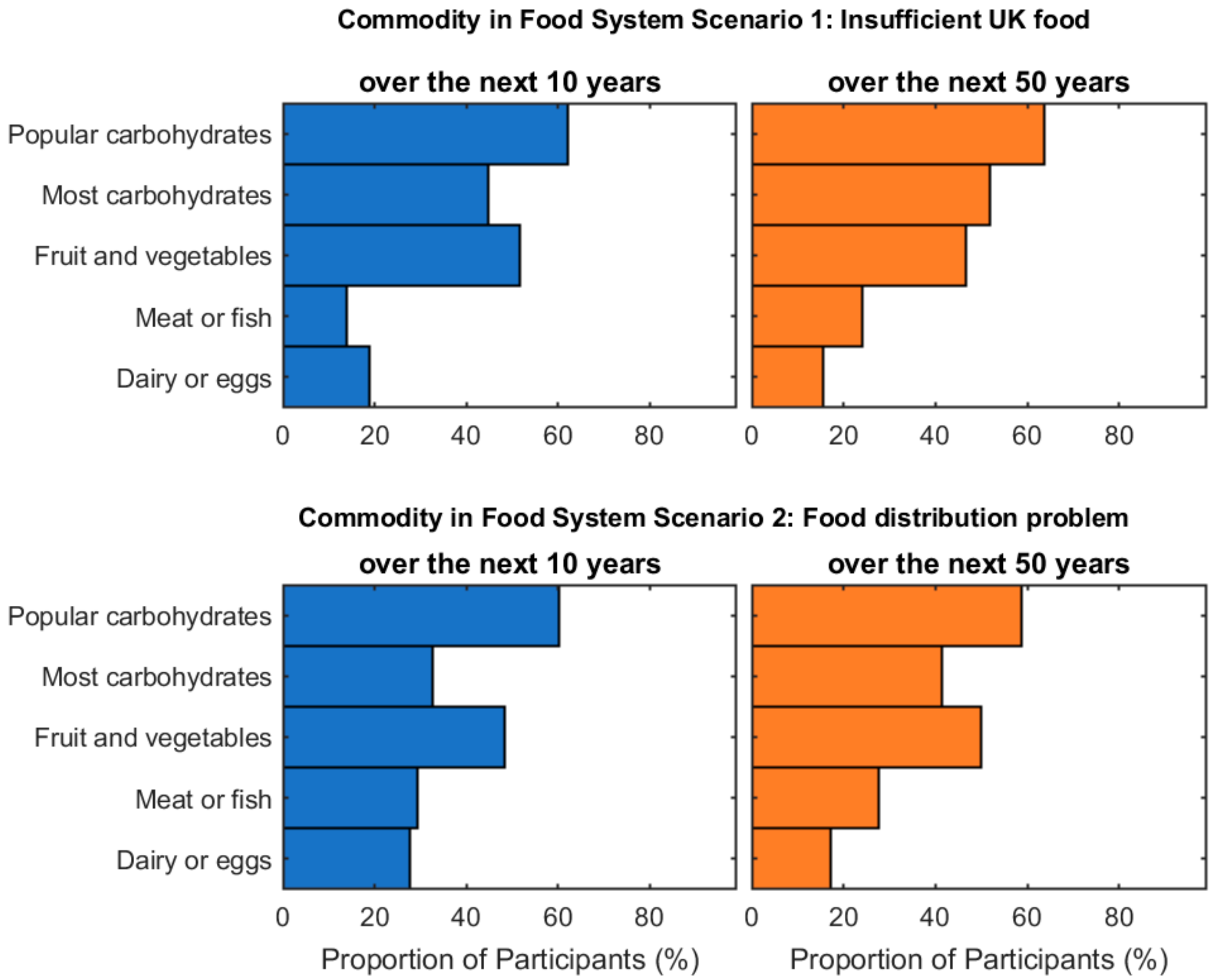

Figure 5. The commodities selected by the participants as being most likely to lead to civil unrest in each Scenario (Scenario 1: **upper panels**; Scenario 2: **lower panels**) for each timeframe (10 years: **left panels**; 50 years: **right panels**).

Other free-text comments related to specific products—such as nuts, imported plant-based foods, tea, pasta and ultra-processed foods—where particular product supply chains may become disrupted. There was also a concern that cost increases of some commodities (such as animal products) may make them unaffordable for parts of the UK domestic consumption market.

Overall, 29% of participants said there is a greater than 20% chance of civil unrest in the next 10 years due to a food distribution problem caused by extreme weather. The vast majority (all but one) of these named carbohydrates as an affected commodity (either popular carbohydrates or most carbohydrates). Over a 50-year timescale, 44% of participants said there is a greater than 20% chance of civil unrest due to insufficient food in the UK. All these cited extreme weather or ecological collapse as a likely cause, and the vast majority (92%) of these named carbohydrates as an affected commodity.

4. Discussion

Food shortages could be caused by a reduction in the amount of food imported from overseas (lack of transport, export or import restrictions or non-availability) or by a catastrophic failure of the UK harvest (through extreme weather, disease or lack of labour, fuel or transport). Even with sufficient food, access can be severely impacted through cost, with 7% of the UK population currently in food poverty [59]. Therefore, future routes to civil unrest via the food system can be characterised as complex and interconnected, with many feedback loops between the various potential causes and compounding factors. During our expert elicitation, this complex system was seen as potentially unstable, with approximately 85% of the expert participants in our survey saying that civil unrest—where 30,000 people in the UK are injured—had at least a 1 in 20 chance of occurring in the next 10 years.

In the past, the UK has faced significant food shortages, in particular during the periods of the world wars. However, the response by the public in accepting rationing, changes in diet and increasing home production avoided catastrophic impacts and indeed saw healthier diets being adopted [60]. More recently, with a high level of awareness about potential food shortages, people have tended to stockpile long-life food, which has made it scarce, even though there may be no immediate shortage [37].

Equity is key to avoiding civil unrest when managing reductions in food availability [61]. With an inequitable distribution, food riots are more likely. Coupled with the rise in social media and sensationalist journalism and with a public expectation that one should be able to buy anything, more or less at the same price, at any time of year, there is a negative feedback loop in the food system that can increase the impact of any disruption.

The most likely cause of food system-linked civil unrest in the UK was judged as extreme weather by our expert participants over both a 10- and 50-year timeframe. Exploring the myriad pathways to food system disruption from extreme weather is highly challenging. Beyond the direct physical impacts on crop establishment, growth and harvest, extreme weather can impact food security through its impacts on the labour and logistics required in food production [62,63], as well as its impact on pests, pathogens, diseases, floods, fires and droughts. It can also initiate cascades in both physical [64] and human systems [65], for example, leading to political crises [66] and, plausibly, war [67].

While climate change was identified as a chronic risk in the recent UK National Risk Register (NRR) [68], of the 89 acute risks identified, only a food contamination event, rated with a 5–25% likelihood over the next 5 years with moderate impact, was identified as a direct food system risk. Within the NRR, a number of other identified acute risks are seen as risk multipliers with indirect impacts on the food system, including nuclear attacks or accidents, pathogens (in particular animal disease) and disruption to communications systems. However, the NRR rates public disorder with a 1–5% likelihood, though without identifying a particular trigger for such an event. Here, we note that it is important to acknowledge that public disorder may be triggered by any of the other identified acute or chronic risks that the UK faces and may be more likely as some of these risks are interconnected, as highlighted by the participants in the expert elicitation.

Causes for our food supply scenarios are not entirely independent. Extreme weather events could, for example, affect the availability of migrant labour as well as crop yield. It may also be that extreme weather only threatens food systems when compounded by other, independent hazards. That is, weather events of a magnitude that may have historically generated little detectable influence on food systems could be catastrophic if occurring alongside war [69] or a pandemic [70]. While not explored in detail in this expert elicitation, some participants highlighted the potential of a climate tipping point—such as a change in the gulf stream (specifically the Atlantic Meridional Overturning Circulation (Amoc) [71]) or collapse of the Amazon rainforest. This could change the predominant weather in the UK or bring permanent disruptions to global food producing areas. Participants also noted the increasing likelihood of climate change impacts over the coming decades. At the very least, over time, degradation of the food system due to climate change is likely to increase its vulnerability to such hazards.

All of the survey results were combined into a “backcasting map” (Figure 6), where the line thickness is proportional to the number of participants choosing the causal connection. This illustrates the significant shift in perceptions on the 50-year timeframe and the strong focus on extreme weather.

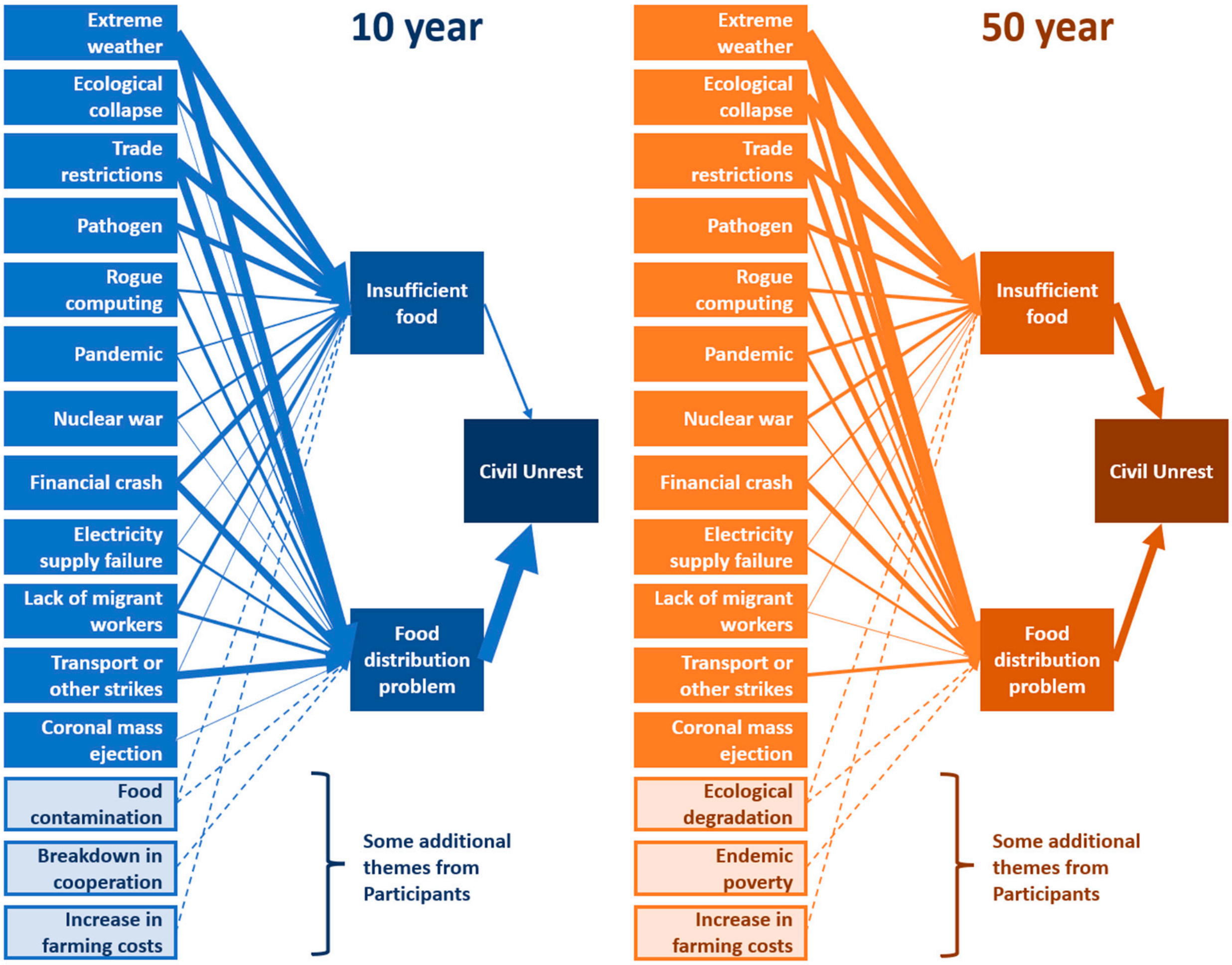

Figure 6. Backcasting map of possible routes to the Societal Event (right of each panel) from the underlying cause (**left**) via the Food System Scenario type (**centre**), indicating expert ranking of the connection using line thickness—for 10 years (**left panel**) and 50 years (**right panel**). Additional themes from the free-text boxes are shown in lighter shaded boxes with dashed lines (these additional themes were not voted on by all participants and, therefore, line thickness is not indicative of ranking).

While participants did rank the causes—with extreme weather, ecological collapse and trade restrictions all deemed important—it is clear from the responses, and, in particular, the free-text responses, that participants felt that it is a combination of factors rather than a single driver that would cause disruption. Additionally, some participants felt that both scenarios (an absolute lack of sufficient calories in the UK and a food distribution problem) are mutually reinforcing. The knock-on from one causal factor to another can create cascading risks [72], with particular combinations of factors such as extreme weather and degraded ecosystems being reinforced through economic and demographic instability, resulting in trade restrictions and protectionism. Therefore, we see that the conceptual model of the food system from our expert participants involves a complex system with multiple interdependencies and connections.

We do note that some of the hazards (such as coronal mass ejection or extreme weather) can be estimated in a way that others (such as nuclear war or rogue AI) cannot. In addition, the impact of a nuclear war would be felt far beyond the food sector. There may be some cognitive bias in responses away from more "exotic" causes towards those that are quantifiable. However, we saw no evidence of this in the responses but do recommend further research to explore this. In addition, while past events are not a good indicator of future impacts, we advocate that data from past events be used to help inform our understanding of potential cascading risks in the future—models lacking these data may be more likely to fail to capture the full extent of connections through complex human systems. For example, downward counterfactual searching [73]—informed by physical modelling of the climate system [74]—is a potentially tractable methodology to help understand and therefore mitigate such complex and potentially catastrophic threats to food security.

Importantly, the diversity in responses that were received, coupled with the need to consider the food system as complex and interconnected, leads us towards the need for more of these types of horizon-scanning exercises which can stress test the UK food system. While research on global catastrophic risks is increasing and global risk surveys highlighting these key issues are more common (e.g., see [75]), there is a need for more focused work which pulls together expert understanding of the likely causes and impacts of such risks. Therefore, we propose that expert elicitation [42] is a useful tool for future risk studies.

5. Conclusions

In this paper, we reported the results of a structured expert elicitation from 58 food system experts on future food system disruption scenarios for the UK. The participants highlighted the potential for both food shortages and food distribution problems leading to civil unrest, with a wide range of causes and no single dominant driver. We found that, over a timescale of 50 years, about one third of the experts thought that a catastrophic event, where more than 30,000 people in the UK were injured as a result of violent protests, was more likely than not.

The food system will face significant challenges in the future and its design needs to be optimised for both resilience and efficiency. We argue that a systematic review of the resilience of the UK's food system to such multi-causal crises is urgently required. To prevent catastrophic impacts, the UK must be prepared to both respond to, and mitigate, likely causes.

To attenuate concerns about food production and supply, government agencies and the private sector should explore and fund options to increase food system resilience in the UK through ecosystem restoration and management, storage and distribution, labour-force conditions, sustainable and resilient agriculture practices (developed in partnership with farmers) and consumer engagement (to build trust in the food system and support behavioural changes including dietary diversification), as well as tackling endemic food poverty and mitigating climate change. The COVID-19 pandemic saw rapid and large-scale changes in food distribution and consumption patterns in the UK, from which lessons need to be learnt.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su152014783/s1.

Author Contributions: S.B. (Sarah Bridle)., A.J. (Aled Jones) K.D., R.B., D.M., L.S., B.C., V.P., T.B. and P.F. conceived the study and devised the survey. S.B. (Sarah Bridle) made the figures from the survey results. A.J. (Aled Jones) and S.B. (Sarah Bridle) drafted the manuscript. A.J. (Aled Jones), S.B. (Sarah Bridle), K.D., R.B., D.M., L.S., B.C., V.P., T.B., P.F., T.K.M., S.H., J.S.H.-H., S.B. (Simon Beard), J.P. (Julie Pierce), J.P. (Jules Pretty), M.Z., A.J. (Alexandra Johnstone), P.S., N.G., M.W., E.P., A.T. (Asaf Tzachor), C.D., C.R., N.W., J.F., C.P., T.Q., J.P.C. and C.M. edited and gave other input to improve the manuscript. T.B., C.B. (Carrie Bewick), R.B., C.B. (Cameron Brown), C.B. (Christopher Brown), P.J.B., A.C. (Andy Challinor), B.C., A.C. (Andrew Cottrell), T.C., K.D., C.D., P.F., J.F., T.G., C.J.G., N.G., R.S.H., S.H., J.S.H.-H., J.I., A.J. (Alexandra Johnstone), T.L., F.L., S.L., T.M., T.K.M., C.M., D.M., S.N., S.P. (Simon Pearson), C.P., J.P. (Julie Pierce), V.P., E.P., J.P. (Jules Pretty), S.P. (Sue Pritchard), T.Q., C.R., D.S., A.S.B., P.S., L.S., M.S., A.T. (Alastair Trickett), A.T. (Asaf Tzachor), A.V., N.W., C.W., D.W., K.W. and M.Z. were the Expert Elicitation Participants who agreed to be named and included as authors. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was approved by the Departmental Ethics Committee of the Global Sustainability Institute at Anglia Ruskin University.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: A spreadsheet of numbers used to create the main figures is included for convenience: https://www.dropbox.com/scl/fi/ydvzqyodak455b8ovu8tb/EE23_data_for_figures.ods (accessed on 7 October 2023), The full cleaned anonymised multiple-choice results are provided here: https://www.dropbox.com/scl/fi/npf0c49klg7ky3y6in1c2/Airtable_EE23_230808_cleaned_anonymised.csv (accessed on 7 October 2023). Free-text comments are included as Supplementary Materials with this paper.

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Appendix A. The Catastrophic Food System Disruption Expert Elicitation Survey

As a food systems expert, we would be grateful for your input to devise distinct catastrophic UK food system disruption scenarios for the purpose of supporting prevention, preparedness, response and recovery planning efforts. Your individual answers will be stored on secure computer systems and your aggregated anonymous responses will form part of a report. Once we have anonymised all responses we will invite you to co-author the report if you are interested in working with us on this.

For this study, we have chosen to focus on the following Societal Scenario:

"Civil unrest has occurred in the UK, as defined by violent injury of >30,000 people in 1 year, due to e.g., violent looting, strikes, demonstrations, or crime including hate crime (i.e., roughly one in 2000 people are injured, which is a factor of 10 greater than the number of injuries in London riots in 2011)."

We will ask you the same questions for two different time periods (A) 10 years and (B) 50 years.

Appendix A.1. 10 Years

Q1. In your opinion, how plausible is this Societal Scenario to occur in the next 10 years

a. Very unlikely (<5%)
b. Unlikely (5–20%)
c. Possible (20–50%)
d. More likely than not (50–80%)

e. Very likely (>80%)

Imagine that the above Societal Scenario has occurred. We now ask you to work backwards in time to consider what type of Food System Scenario might have contributed to it. We consider two distinct Food System Scenarios and would be grateful for your input on their plausibility, some details, and how they might connect with the above Societal Scenario.

Food System Scenario 1

"There are now insufficient calories available to feed the UK population, and this has contributed to the Societal Scenario"

Food System Scenario 2

"There is a food distribution problem leading to geographically isolated pockets of hunger, despite adequate total calories being available to feed the UK population, and this has contributed to the Societal Scenario"

Imagine you are living 10 years in the future and that the Societal Scenario has occurred, and you are now looking back in time.

Q2. Which Food System Scenario do you think is most likely to have contributed to the Societal Scenario?

[single select]

Food System Scenario 1 (insufficient UK food)

Food System Scenario 2 (food distribution problem)

To make scenario planning more effective, it is helpful to fill in some details for each Food System Scenario, including the cause and which parts of the food system are involved.

Q3. What do you think is most likely to have caused Food System Scenario 1? (Please select up to 3 options—that could have occurred individually or in combination)

a. extreme weather (including storm surges, flooding, snow, drought)
b. nuclear war
c. trade restrictions or protectionism
d. pandemic
e. financial crash
f. animal or plant pathogen
g. ecological collapse
h. computer virus, rogue AI or similar
i. breakdown of electricity supply
j. coronal mass ejection
k. transport strikes
l. lack of migrant workers

If there are other causes in your top 3, which are not listed above, please state them here.

Q4. Within Food System Scenario 1, which commodity shortages do you think are most likely to have led to the Societal Scenario (please select up to 2)?

a. popular carbohydrates (wheat/bread/pasta/cereal)
b. most carbohydrates (including oats, potatoes, barley)
c. fruit and vegetables
d. dairy or eggs
e. meat or fish

If there are other commodities in your top 2, which are not listed above, please state them here.

Q5. What do you think is most likely to have caused Food System Scenario 2? (Please select up to 3 options—that could have occurred individually or in combination)

a. extreme weather (including storm surges, flooding, snow, drought)
b. nuclear war
c. trade restrictions or protectionism
d. pandemic

e. financial crash
f. animal or plant pathogen
g. ecological collapse
h. computer virus, rogue AI or similar
i. breakdown of electricity supply
j. coronal mass ejection
k. transport strikes
l. lack of migrant workers

If there are other causes in your top 3, which are not listed above, please state them here.

Q6. Within Food System Scenario 2, which commodity shortages do you think are most likely to have led to the Societal Scenario (please select up to 2)?

a. popular carbohydrates (wheat/bread/pasta/cereal)
b. most carbohydrates (including oats, potatoes, barley)
c. fruit and vegetables
d. dairy or eggs
e. meat or fish

If there are other commodities in your top 2, which are not listed above, please state them here.

Appendix A.2. 50 Years

We now ask the same questions again, but this time we would like you to imagine a point in time 50 years in the future (2073).

Q7. In your opinion, how plausible is this Societal Scenario to occur in the next 50 years

a. Very unlikely (<5%)
b. Unlikely (5–20%)
c. Possible (20–50%)
d. More likely than not (50–80%)
e. Very likely (>80%)

Q8. Which Food System Scenario do you think is most likely to have contributed to the Societal Scenario?

[single select]

Food System Scenario 1 (insufficient UK food)

Food System Scenario 2 (food distribution problem)

Q9. What do you think is most likely to have caused Food System Scenario 1? (Please select up to 3 options—that could have occurred individually or in combination)

a. extreme weather (including storm surges, flooding, snow, drought)
b. nuclear war
c. trade restrictions or protectionism
d. pandemic
e. financial crash
f. animal or plant pathogen
g. ecological collapse
h. computer virus, rogue AI or similar
i. breakdown of electricity supply
j. coronal mass ejection
k. transport strikes
l. lack of migrant workers

If there are other causes in your top 3, which are not listed above, please state them here.

Q10. Within Food System Scenario 1, which commodity shortages do you think are most likely to have led to the Societal Scenario (please select up to 2)?

a. popular carbohydrates (wheat/bread/pasta/cereal)

b. most carbohydrates (including oats, potatoes, barley)
c. fruit and vegetables
d. dairy or eggs
e. meat or fish

If there are other commodities in your top 2, which are not listed above, please state them here.

Q11. What do you think is most likely to have caused Food System Scenario 2? (Please select up to 3 options—that could have occurred individually or in combination)

a. extreme weather (including storm surges, flooding, snow, drought)
b. nuclear war
c. trade restrictions or protectionism
d. pandemic
e. financial crash
f. animal or plant pathogen
g. ecological collapse
h. computer virus, rogue AI or similar
i. breakdown of electricity supply
j. coronal mass ejection
k. transport strikes
l. lack of migrant workers

If there are other causes in your top 3, which are not listed above, please state them here.

Q12. Within Food System Scenario 2, which commodity shortages do you think are most likely to have led to the Societal Scenario (please select up to 2)?

a. popular carbohydrates (wheat/bread/pasta/cereal)
b. most carbohydrates (including oats, potatoes, barley)
c. fruit and vegetables
d. dairy or eggs
e. meat or fish

If there are other commodities in your top 2, which are not listed above, please state them here.

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