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Exploring global food system shocks, scenarios and outcomes

Abstract

Globalised food supply chains are increasingly susceptible to systemic risks, with natural, social and economic shocks in one region potentially leading to price spikes and supply changes experienced at the global scale. When projections extrapolate from recent histories and adopt a 'business as usual' approach they risk failing to take account of shocks or unpredictable events that can have dramatic consequences for the status quo as seen with the global Covid-19 pandemic. This study used an explorative stakeholder process and shock centred narratives to discuss the potential impact of a diversity of shocks, examining system characteristics and trends that may amplify their impact. Through the development of scenarios, stakeholders revealed concerns about the stability of the food system and the social, economic and environmental consequence of food related shocks. Increasing connectivity served as a mechanism to heighten volatility and vulnerability within all scenarios, with reliance on singular crops and technologies (i.e. low diversity) throughout systems highlighted as another potential source of vulnerability. The growing role of social media in shaping attitudes and behaviours towards food, and the increasing role of automation emerged as contemporary areas of concern, which have thus far been little explored within the literature.

Key words: shocks; food system; stakeholders; connectivity; diversity; social media

1. Introduction

The ability to trade and transport food across the globe allows a greater degree of specialisation and increased efficiency (Godfray et al., 2010), facilitating shifts in food production to the cheapest locations (McKenzie, 1953; Hertel, 2011). Consequently, food calories traded in the international market more than doubled between 1985 and 2009 (D'Odorico et al., 2014). As trade links have flourished, food self-sufficiency has become less important, with around 80% of the global population now living in net food import countries (Porkka et al., 2013). The UK imports around half of its food, with fruit and vegetables, meat and beverages being the largest imported commodity groups by value (Defra, 2018). In 2018, it was the largest producer of sheep and goat meat of the EU-28 Member States and the third biggest producer of wheat, milk and beef. The food sector contributes £121 billion a year to the UK economy, with food exports accounting for £22 billion of that figure (Defra, 2019). A more globalised food system means many consumers benefit from reduced food prices and wider product choice (Manning & Baines 2004), however specialisation means many global food staples are produced by a limited number of countries (Puma et al., 2015). This creates key regions upon which a significant proportion of the world's population depend e.g. The United States and China produce approximately 60% of the world's maize (Kent et al., 2017), with some important 'bread-basket' regions becoming increasingly vulnerable to shocks (Richardson et al., 2018).

As global trade in food has increased, so too has the interconnectedness of the agricultural sector in energy and finance markets (Naylor, 2011: Tadasse et al. 2016). Such changes have potentially led to new and more complex sources of shocks and additional drivers of trends. This was demonstrated in 2007 and 2008 when financial speculation, country level biofuel targets, the corn ethanol boom and specific protectionist policies contributed to price inflation of key commodities across the globe (Tadasse et al. 2016). Analysis of the 2007/08 price spikes highlights the increasing range of factors that can contribute to the volatility of global food price, with droughts in grain producing nations, an increase in the price of oil (triggering increased fertiliser and transport costs) and currency fluctuations all thought to have contributed to price surges and volatility (Piesse & Thirtle 2009; Heady, 2011).

Relatively short term price spikes can lead to undernutrition and food poverty, with longer term health impacts on children and the vulnerable (Arndt et al., 2016; Vellakkal et al., 2015). The 2007/2008 and

2010/2011 spikes had a severe impact on poorer members of society who spend a large proportion of their income on staple food, increasing the depth of poverty for those already poor (Compton, Wigging & Keats, 2010). The economic uncertainty that can accompany volatility in food prices has the potential to disproportionately affect small businesses with a lack of resources (von Braun & Tadesse, 2012). The documented impact of episodic price spikes and the changing nature of the food system highlight the increasing need to study converging factors that lead to shock events and subsequent volatility in food prices (Tadasse et al., 2016). The outbreak of Covid-19, with unprecedented lock-downs enforced in many countries across the globe, highlights the importance of considering a greater range of shock events and their potential impacts in futures planning.

Taleb (2007) termed unpredictable events with extreme repercussions: 'Black Swans', and emphasised the importance of considering such outliers in future planning. Unpredictable events that affect the food system can have severe and far reaching consequences, yet thus far remain relatively underexplored. The food system encompasses all activities involved in the production, processing, transportation and consumption of food. Recent food related shocks have demonstrated that localised and sometimes relatively minor disruptions to the food system can have a sizeable impact on the global price of key commodities such as wheat, maize, soybean and rice (Bailey et al., 2015; Tadasse et al., 2016). However, consideration of food system shocks tends to be retrospective, allowing decision makers within business and policy to plan for similar shocks occurring again, without generating a wider discussion of what might happen should new and complex shocks occur.

Previous work has explored business as usual or plausible future climate and socio-economic pathways in relation to the food production and security (Rosenzweig et al. 2001, Wheeler & von Braun, 2013; Bailey et al. 2015; Lunt et al., 2016). However, there is thus far a paucity of research into how a diversity of future shocks could destabilise various aspects of the food systems. It is important to understand how current trends and food system characteristics might interact to create or exacerbate shocks if we are to develop appropriate adaptation and mitigation measures to minimise their effects. This requires a wider exploration of a variety of shocks and consideration of potential impacts.

We identify and consider the impacts of shocks (i.e. sudden or unanticipated events) and trends (i.e. incremental developments) on the stability of future food systems, primarily aiming to identify important trends and potential shock sources that have so far been under explored. In recognising cross cutting vulnerabilities that have become an intrinsic part of contemporary food systems, we can begin to consider how we might plan for, and alleviate the most detrimental impacts of future shock events (von Braun & Tadasse, 2012).

2. Methods

2.1 A stakeholder led approach

A stakeholder-led exploratory approach was used to generate scenarios that consider near future (those that might occur in the next 0-25 years) shocks to the food system and explore characteristics and trends that may contribute to and amplify their impact.

Scenario planning is a participatory methodology that can be used at the science-policy/science-industry interface when exploring complex and uncertain situations (Duckett et al., 2017). Our methodology comprised standard and accepted elements of the process as defined in previous literature including i) defining the scope of the question, ii) identifying relevant stakeholders, iii) recognising fundamental trends and uncertainties, v) development of preliminary scenario narratives and vi) checking for completeness and clarity (Schoemaker 1995; Foster 1993).

A stakeholder mapping exercise non-randomly identified a diverse range of organisations from across the UK food system to participate in this study. The mapping process involved considering all sectors and industries part of, or closely linked to the food system, and identifying representatives from organisations, businesses (small, medium and large), government departments and NGOs that could contribute to the study. Stakeholders at different levels within different sectors were engaged to provide diverse and often contrasting expertise and experiences. The scope of the work required the recruitment of participants with a good knowledge of the food industry, but also of participants with an understanding of the wider policy, environmental, economic and social systems linked to it. All stakeholders that responded to contact attempts were invited to participate in the project and attend a workshop in July 2017. The final stakeholder group included representation from research, policy, retail, NGO's, production, energy and insurance sectors, facilitating an holistic insight of a multi-faceted food system. This stakeholder group had a roughly equal gender mix and included individuals aged between 20 and 60+.

2.2 Workshop

Twenty participants attended the facilitated workshop in July 2017. Attendees were first asked to draw on their knowledge to establish a list of factors (or 'drivers') that are known to affect the food system, identifying trends and areas of uncertainty where high impact shocks could originate. Participants were not limited by scale and allowed to consider local and global drivers as they saw fit. Whilst all participants were from the UK it was not thought necessary to restrict stakeholders to consider UK only examples or impacts during the workshop. As discussed, food systems are complex and not only affected by local or UK centred events. In addition many of the individuals attending the workshop worked for organisations or industries with an international or global component, or had occupied previous roles with a wider geographical focus. The opening session allowed stakeholders to draw on their individual areas of expertise and work together to group drivers into categories. In groups, participants were then asked to construct four fictional 'headline scenarios' that incorporated brief details about how a shock or trend may influence food systems, linking one or more shocks with a series of consequences. They were encouraged to consider extreme events with a low probability of occurrence, and asked to explore how current trends may lead to and exacerbate these shocks.

A facilitated plenary session then enabled participants to discuss the headline scenarios and group consensus was reached (by use of a voting system) to select the scenarios that would be developed in more detail. Stakeholders chose four different headline scenarios for further elaboration in the subsequent session and moved groups when necessary to work on the scenario of most interest to them. In four groups (capped at five individuals), stakeholders developed these storylines in more detail and described the potential consequences of an initial shock. Whilst smaller groups worked on each scenario all stakeholders were given the opportunity to comment on the storylines during plenary, a carousel session, and post workshop questionnaire. This ensured that all participants were able to add insight to the scenarios both during, and after the workshop and clarify any aspects that might have been misinterpreted on the day.

Through the development of scenarios, stakeholders were encouraged to consider how plausible future events might unfold, allowing an increased understanding of key areas of concern and potentially important sources of vulnerability (Schoemaker, 1991; Godet, 2000; Amer, Daim & Jetter, 2013). Stakeholders were asked to draw on their knowledge and experience but were not limited to considering likely futures, nor asked to justify their assumptions or quantify the likelihood of such events occurring. The aim of the scenario development process was to identify and explore the types of trends and shocks that concerned stakeholders most and which have thus far been underexplored.

Scenarios were developed and then described and shared during the workshop. However, groups were not asked to write a polished version of their narrative during the session. The scenarios described subsequently were formed into coherent stories by the researchers post workshop, although the wording and descriptions provided by stakeholders were utilised wherever possible when producing the narratives. The final wording was shared with those involved to check for accuracy of any interpretations that may have been made.

3. Results

In the opening session stakeholders identified a range of shocks and trends that influence the food system. These included environmental concerns such as increasing pests/diseases, a loss of biodiversity and extreme weather events (most of which were discussed as being exacerbated by climate change), technological advancements, which were thought to pose both challenges and opportunities, and a variety of social drivers ranging from shifting food preferences, to trade restrictions to conflict. Stakeholders then moved on to developing 16 'headline' scenarios that briefly described a hypothetical shock event (see Appendix A for detail) and one or more consequences. Stakeholders selected four of the sixteen headline scenarios that they wanted to take forward (i.e. automation, extreme weather, financial speculation and monoculture vulnerability) to develop into detailed narratives.

3.1 Scenarios overview

Each of the four scenarios described a different shock to the food system, and whilst the origin of each shock was different the characteristics of the food system that increased the scope and scale of the consequences were found to be similar (Figure 1).

In each scenario, stakeholders described a lack of diversity, either in regards to the type of crop grown or the systems used to produce and distribute produce. For example, in the automation scenario stakeholders communicated particular concerns regarding increasing reliance upon technology within food systems. They recognised that technology has led to increases in productivity, but that a high degree of connectivity and a lack of diversity in the food system, both in regards to the hardware and software used as well as a reduced number and range of producers and suppliers, can be a source of food system vulnerability. Each scenario also highlighted how highly-connected food systems allowed widespread perturbation of the effects, beyond the area initially impacted by the shock. The growing impact of media and social media on behaviours and decision making was a topic discussed throughout the day. A food fad triggered by social media contributed to a shock in one of the four scenarios, representing a new form of connectivity within the food system.

Table 1. A summary of key themes that featured across the four developed scenarios. System characteristics describe the pre-shock world and trends within food systems whilst the shock consequences detail the aftermath of the shocks, showing themes that occurred in two or more of the scenarios.

Many of the consequences described in the scenarios were socio-economic, with crop loss leading to a loss of jobs and livelihoods as well as volatile food prices and social unrest. Disruptions to food availability, or fears over potential disruption are known to cause widespread panic and this was conveyed in the scenarios. The environmental consequences of increasingly intensive practices (e.g. the wide scale production of soybean/novel health foods) and the destruction of habitat as new land is brought into agricultural production was present in three of the four scenarios and concerns over animal welfare and waste disposal issues were mentioned in two.

The full scenarios can be found below with accompanying illustrations. These scenarios were developed to explore ideas and potential consequences of future shocks, in order to understand key areas of concern and perceived vulnerabilities. Stakeholders were not asked to justify the scenario pathways or quantify the likelihood of the unfolding events, just to describe outcomes they thought might occur.

Scenario 1. Automation

In a not too distant future, a reduced number of suppliers and producers enable greater efficiency and automation technology becomes so advanced that the trucks transporting food from the producer to the supermarket no longer need drivers. Automated processes control many aspects of the food system (from production to point of sale) such as stock control, storage temperatures, transport and finance. This creates a highly efficient system and less redundancy. Computer driven systems allow maximum efficiency and increased profits, but these highly connected systems and narrow margins leave the system vulnerable to accidental failure (e.g. computer bug, or geomagnetic storm) or malicious action (e.g. cyber-attack).

For example, a cyber-attack of sufficient severity shuts down automation control systems, leading to supply chain disruptions. There is very little storage capacity in the system, as highly efficient systems rendered this unnecessary and food shortages arise when the trucks that transport food from the farmer to the supermarkets are unable to operate. These shortages lead to mass panic buying and ultimately civil unrest, with state intervention required at supermarkets. Food that cannot be transported from the farm spoils creating economic loss and a waste disposal issue. The technology involved in crop production is also impacted by the initial attack, leading to reduced yields at those farms unable to quickly restore functional computerised systems. Livestock farming is negatively affected by feed stock shortages and in the longer term, access to antibiotics and other pharmaceuticals is hindered by the transport disruptions, creating animal welfare issues. Even when control systems are restored, recovery of the system is expected to take weeks and requires government intervention. Wider economic instability ensues. Farmers resort to older methods and consumers to shorter, local supply chains as faith in technology waivers.

Figure 1. ***Driverless trucks break down. Automated food production systems are developed including driverless tractors and lorries that are subject to technological failures when a cyber-attack occurs.***

Scenario 2: Extreme Weather

A developing economy is heavily reliant on the export of a high-value raw commodity. It is the biggest producer of the crop globally and has thus invested heavily in the infrastructure needed to successfully produced and transport the good. The commodity is a key ingredient in many processed goods consumed across the globe, with hundreds of factories in disparate countries involved in processing it into thousands of end products.

A drought in the region leads to the widespread loss of the crop. Income losses lead to localised civil unrest, with negative consequences for infrastructure and transport routes in and out of the country. Humanitarian aid and military intervention are required as poverty increases and civil unrest escalates. The situation increases migration causing increased social and political instability beyond the initial drought region.

Additionally, the crop failure leads to a price spike in the raw and associated commodities. There are job losses further afield in processing industries and diets change as consumers struggle to access certain products. Investment in production shifts to other areas, exacerbating the negative long-term effects for drought effected region. Land use changes occur in other countries that seek to meet the supply/demand, with associated environmental and social impacts.

Figure 2. ***Drought causes civil unrest in a developing economy highly dependent on one crop. Processing industries in many disparate countries are affected by a shortage in a key commodity and shifts in land use occur as new regions seek to meet supply/demand.***

Scenario 3: Financial speculation

In a not too distant future a surge of social media interest in health foods leads to increasing financial speculation in agricultural commodities, triggered by a desire to profit from future food price spikes. Higher potential profits lead to increases in land value and consolidation in farming activities as large agricultural production companies become more dominant. Fewer, larger farms lead to sizable areas of monoculture.

Monocultures reduce habitat heterogeneity and intensify farming, which increases environmental harm and negatively affects pollinators who rely on a diversity of food sources. A loss of diversity in crop variety increases vulnerability to agricultural pests and diseases. Larger farms and greater homogenisation also leads to greater flood risk, as non-crop vegetation is removed and ploughing is no longer staggered. The price of food become more volatile as real and perceived threats to production (e.g. unfavourable weather) are magnified by market speculations. Volatility in food price means poorer consumers face hunger and associated health problems during periods of high prices, with the potential to lead to social unrest.

Figure 3. ***Financial speculation spurred on by social media trends prompts an increased investment food production. High potential profits increases the number of multinational companies and reduces the number of small farms. Monocultures and intensive farming lead to environmental degradation.***

Scenario 4: Monoculture Vulnerability

A single plant variety dominates soybean production in South America. The success of this variety has made other cultivars largely superfluous. Plantations are owned by multinational companies and one region in particular is a globally important producer of soybean for livestock feed.

A new pathogen emerges in South America that destroys a sizeable proportion of global soybean. This causes thousands of job losses as farmers lose their crops and the multinational owners lose their investors. There is a shortage of feed for livestock leading to greater pressure on Amazon deforestation to produce more soybean. Cattle are fed on grass and barley causing barley prices to increase. Pigs and poultry have no easy alternative feed and animals are culled early.

The price of meat increases and regulations are relaxed to allow food waste to be used as feed, with potential health implications, as well as for the current waste stream usage production, e.g. biogas. Media and social media coverage of the situation leads to increased public awareness of vulnerabilities within the food system. This coupled with a struggling meat industry leads to dietary changes and increased vegetarianism, as many consumers are unable to afford meat.

Figure 4. S*oya bean exports obliterated by emerging pathogens. The loss of a key source of protein for both humans and livestock creates a massive strain on the meat industry resulting in increased vegetarianism.*

4. Discussion

Across the four scenarios two common aspects of the modern food system were identified as exacerbating the impacts of shocks: an increase in connectivity and a loss of diversity. These aspects also emerged during the creation of the 16 headline scenarios (Appendix A) as central areas of vulnerability. Whilst an increase in connectivity and a loss of diversity, have previously been recognised as risks within the food system (Rotz & Fraser 2015, Fraser et al., 2005), a trend towards automation and the expanding influence of the media (and social media in particular) in causing or exacerbating food system shocks have not yet been considered.

4.1 High connectivity

A high degree of connectivity allows disturbances to pass rapidly from one individual, landscape or technological system to the next (Rotz & Fraser, 2015) such as, for example, the rapid spread of Covid-19 and associated consequences. Risks intrinsic to highly connected systems were highlighted throughout the scenarios. For example, the risk that increased connectivity aids the spread of pests and diseases, or that transport and distribution systems, increasingly connected by technology, could come under threat , e.g. from a cyber-attack. Greater interconnectedness between countries brought about by lower transport costs and an enhanced movement of people and material resources can lead to efficiencies within the food system, but consequently create vulnerabilities and new forms of risk exposure. The impact of a relatively short disruption to transport systems was seen recently in the UK, when snow and adverse weather conditions left supermarkets without milk and bread (BBC 2018; Spary, 2018).

Stakeholders considered how an increasingly connected world has enhanced the speed of information flows, resulting in local actors, processes and events having a disproportionate influence on global developments (Young et al., 2006). There are significant benefits in rapid information transfer and the economies of scale that create business clusters with greater intellectual, technological and production resources. Whilst these benefits were acknowledged, during the scenario development exercise, discussions focused on the risks of a more connected world, rather than the benefits that connectivity affords.

4.1.1 Increased automation

Increasing automation has led to a food system that is more connected and more reliant on integrated technologies than ever before. Automation can be defined as the execution by a machine agent of a function that was previously carried out by a human being (Gandino et al. 2009). Technological advancements are allowing increasing automation throughout food supply chains, from production to consumer purchasing. For example, precision agriculture uses technology to manage production at a site specific level offering improved resource efficiency and enhancing the quality and quantity of agricultural produce (Gebbers & Adamchuk, 2010), whilst machine vision systems that incorporate near infrared inspection systems are now used for quality management, e.g. the rapid grading of fruit and vegetables (Kondo, 2010). A greater degree of automation can also be found in packaging and transportation (Pingali, 2006) helping to improve quality and safety control, whist super markets increasingly offer self-scan and scan as you shop options that reduce the number of staff required to operate till points.

Whilst opportunities for automation are increasing, the level of automation within the food system is highly variable (Ilyukhin, Haley & Singh, 2001) and often dependent upon firm size. Automation is usually a feature of larger enterprises with greater assets, as the initial cost involved in purchasing and installing computerised systems can be sizable.

Whilst automation within the food system can allow marked increases in efficiency, safety and quality, it also provides a new area of risk should technology fail or systems become subject disruptions or attack. The potential of cyber-attacks to wreak havoc was seen in May 2017, when virus launched using WannaCry (or WannaCrypt) infected 230,000 computers in 150 countries, with notable impact on telecommunications, transportation, shipping and healthcare (Ehrenfeld 2017). Whilst attacks with such wide reaching consequences are thus far rare, the interconnected nature of, widespread dependence on, a relatively limited number of systems suggests they may become more common.

4.1.2 Media and social media

Perceived risks, or indeed the perception of benefits, can potentially lead to realised shocks within the food system. Past food scares including the contamination of beef products with horsemeat across Europe (Verbeke, 2013), E.coli contamination in Germany (Mellmann et al., 2011) and the 2008 dioxin crisis in Ireland (Shan et al., 2013) provide prime examples of the power that the media has in communicating risk (McClusky & Swinnen 2011). Shifting food demand following media and social media stories is a relatively recent possibilty and social media platforms now offer a powerful and rapid mechanism for widescale communication (Rutsaert et al., 2013) and trend setting (Asur & Huberman, 2010).

As well as publicising the risks associated with some foods (Rutsaert et al., 2013), media and social media platforms also provide a forum for discussion of preferences (Vidal et al., 2015) and as such are increasingly used by advertisers to target consumers (Chu et al, 2013). During our workshop stakeholders speculated that a growing demand for ‘health foods’ could have far-reaching consequences if social media interest leads to a surge in demand for these commodities.

In Mexico, it is now more profitable to grow avocados for export than it is to sell the crop domestically (Shumeta, 2010), whilst in Bolivia to has been reported that local people can no longer afford quinoa, a once staple grain, due to western demand and rising prices (Blythman, 2013). Due to increasing profits in avocado production, forested areas are being cleared to plant young avocado trees (Bravo-Espinosa et al., 2014). Relative to most other crops grown in Mexico, avocado is relatively resource intensive to produce, requiring large inputs of water as well as fertilizer and pesticide treatments, which can have further detrimental impacts on the environment (Nelson, 2016). Whilst an increased demand for ‘health foods’ such as avocado and quinoa have not thus far been linked to social media activity there is an increasing body of research demonstrating the ability of social media to set trends and agendas in relation to technology, entertainment, politics and the environment (Asur & Huberman, 2010; Perrin 2015) and it is thus highly likely it will do the same for food.

The internet is now a key channel where consumers gain information about the benefits and risks surrounding food (Jacob, et al., 2010; Redmond & Griffith, 2006; Tian & Robinson, 2008), with the rise of Twitter, Facebook, Instagram etc. allowing them to actively participate in communicating with one another (Mangold & Faulds 2009). The impact that social media can have on food preferences and aversions and how this may impact the stability of food systems is thus far been underexplored and warrants further examination.

4.2 Low diversity

A lack of diversity within many aspects of the food system was identified as another key area of vulnerability. Whilst specialisation has led to efficiency gains allowing us to produce more food at a lower cost (Godfray 2010), more homogenous, intensive practices that can reduce the costs associated with farming can also result in increased environmental harm. In the United States, four crop species dominate production, three of which are key food staples, with wheat, maize and soya bean (along with cotton) accounting for over two thirds of the cropland in the US creating large areas of homogenised landscapes (Margosian et al. 2009). Through the scenario development process concerns were expressed about large scale crop losses in low-diversity systems, as well as fears over the environmental consequences of increased homogenisation. Many studies show strong correlations between crop homogeneity and declines in on-farm biodiversity (Benton et al. 2003; Hooper et al., 2005; Potts et al., 2010) with few crops and no rotation leading to a reduction in key ecosystem services such as pollination and soil quality (Goulson, 2010; Öckinger & Smith 2007; Tilman et al. 2002), a concern raised by stakeholders in both the headline and detailed scenarios.

A lack of diversity in crop varieties and animal breeds can increase the potential for rapid disease spread (Margosian et al., 2009; Ratnadass et al., 2012), as was detailed in scenario 4 (Monoculture vulnerability). In order to sell their produce to supermarkets farmers face mounting pressure to produce crops that conform to a particular physical appearance. Cultivars are increasingly selected for their shelf life and ability to withstand long distance transport, rather than being seasonally appropriate, tasty and of high nutritional value (Weis, 2010). A reduced variation in the number of crop varieties grown and increased commodity specialisation has been shown to increase a farmer’s vulnerability to both ecological and economic risk (Smithers and Johnson 2004).

In recent decades, there have been major trends towards more intensive farming practices and larger farm sizes, coupled with a concentration in the production of agricultural inputs (Rotz and Fraser, 2015). Currently, four companies produce more that 60% of global agrochemicals (Clapp & Fuchs 2009; McMichael 2010). Similar concentrations of power are found in trade and distribution, with five companies controlling approximately 90% of the global grain trade and thirty of the largest retailers controlling one third of world grocery sales (Clapp and Fuchs 2009).

The homogenisation of farmland and concentration of agricultural input production means fewer producers are responsible for providing a larger proportion of the food consumed. This can result in a smaller number of people or organisations having a greater control over price (Rotz & Fraser 2015), a concern expressed by stakeholders when discussing financial speculation in wheat production.

A lack of redundancy within the food system was discussed within several of the scenarios. Stored or stockpiled food can provide a safety net in the event of a production shock, however increasingly efficient systems have led to a reduction in food storage generally. Whilst a reduction in food sent for stockpiling can increase the amount of food available to tackle day to day food security, it has the potential to increase food insecurity when shocks occur.

At the time this article was written, the Covid-19 pandemic was causing devastation across the globe, at a scale and severity not seen since the Spanish influenza outbreak in 1918 (Mazzucato, 2020). It has resulted in the fastest, deepest economic shock in history (Roubini, 2020), with dramatic impacts on food systems. It is unclear what the full suite of consequences will be, but many of the outcomes described in the scenarios here have already come to fruition, including disruption to food availability, widespread panic and loss of livelihoods. The strain on the food system has only begun with the UN voicing concerns that measures put in place to halt the spread of the pandemic could lead to global food shortages, with a move towards protectionism and the shortage of on-farm workers key areas for concern (Harvey, 2020).

5. Assessment of the method

The outcomes of this workshop demonstrate that those operating within the food system are aware of, and concerned with key trends within modern food systems, highlighting the value of further research in this area. Participatory research helps to facilitate culturally and logistically appropriate results (Jagosh et al., 2012, Reed 2008) and increases the likelihood that findings will be of wider use for cross sector decision making. Stakeholders operating within the system being studied are well placed to describe 'pathways' to futures, including interconnections between component parts of the system that might otherwise be missed (Reed 2008; Rounsevell & Metzger, 2010).

Stakeholder participation is a key component in developing research outputs that are relevant for business, industry and policy and that can be used outside of academic settings (Philipson et al., 2012; Gramberger et al., 2015). Scenario development adds a richness to futures analysis that cannot be provided by model outputs and a purely quantitative approach to exploring the future. By engaging a wide range of stakeholders in the scenario development process, we were able to generate a more diverse set of outcomes than we would have if individuals were working alone or with individuals from within their own industry. The diversity of knowledge within the stakeholder group coupled with the workshop setting encouraged the collaborative production of outcomes, which are thus more likely to be relevant to a range of parties.

Whilst those operating within the food system have expertise that allows them to understand the impact shocks and trends may have, few would claim to have a truly holistic view of the system as a whole and the intricacies of factors that now affect it. Despite a diversity of stakeholders attending the workshop those present felt that further expertise would help improve the saliency and credibility of the scenarios developed. Whilst it was felt that the financial world has an increasingly large impact on food production, stakeholders acknowledged a gap in their understanding of this area in particular. Stakeholders also commented that having representation from a wider geographic area would have been beneficial as participants were from the UK only, whilst the scenarios produced were more globally focused. Due to the complex and dynamic nature of the food system, seeking the expertise of a range of actors operating at various scales and representing multiple sectors is important.

If research is to be efficiently targeted to develop effective solutions then it must first determine and understand the concerns of those operating within the system it seeks to influence. It must then work with and be steered by those who are able to affect change; for example the farmers who could diversify the crops they grow, the policy makers that choose how countries respond when shocks occur, and the insurance and finance sectors that provide signals to businesses and consumers alike.

6. Conclusions

To successfully plan for and alleviate the impacts that future shocks might have we must first recognise new sources of vulnerability, which are becoming an intrinsic part of contemporary food systems. Here a group of food system stakeholders took a shock based approach to generate scenario storylines. The four scenarios highlighted known vulnerabilities within the food systems; high connectivity and low diversity, but also revealed novel shock sources and modern trends; increased automation, the role of media/social media, which have thus far been underexplored. As suggested in the scenarios here and demonstated by the Covid-19 pandemic it is no longer sufficient to consider projections based on a 'business as usual' approach to the future. Instead research needs to work in partnership with industry and policy to consider how existing food supply chain vulnerabilities may interact with modern food system characteristics and to better understand how new risks and future shocks might affect food security.

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References

1. Amer, M., Daim, T.U. and Jetter, A. (2013). A review of scenario planning. *Futures*, *46*, 23-40.
2. Arndt, C., Hussain, M.A., Salvucci, V. and Østerdal, L.P. (2016). Effects of food price shocks on child malnutrition: The Mozambican experience 2008/2009. *Economics & Human Biology*, *22*, 1-13.
3. Asur, S. and Huberman, B.A., 2010, August. Predicting the future with social media. In *Proceedings of the 2010 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology-Volume 01* (492-499). IEEE Computer Society.
4. Bailey, R., Benton, T.G., Challinor, A., Elliott, J., Gustafson, D., Hiller, B., Jones, A., Kent, A., Lewis, K., Meacham, T. and Rivington, M. (2015). Extreme weather and resilience of the global food system: Final project report from the UK-US taskforce on extreme weather and global food system resilience. *UK: The Global Food Security Programme*.
5. Benton, T.G., Vickery, J.A. and Wilson, J.D. (2003). Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology & Evolution*, *18*(4), 182-188.
6. BBC News. 'Scots told to be 'patient and sensible' after weather hits food supplies. (2015). www.bbc.co.uk/news/uk-scotland-43258900 (accessed 13th May 2018).
7. Bravo-Espinosa, M., Mendoza, M.E., Carlón Allende, T., Medina, L., Sáenz-Reyes, J.T. and Páez, R. (2014). Effects of converting forest to avocado orchards on topsoil properties in the trans-Mexican volcanic system, Mexico. *Land Degradation & Development*, *25*(5), 452-467.
8. The Guardian. *'Can vegans suffer the unpalatable truth about quinoa?'* Blythman, J. (2013) https://www.theguardian.com/commentisfree/2013/jan/16/vegans-stomach-unpalatable-truth-quinoa (accessed 09 September 2017).
9. Chu, S.C., Kamal, S. and Kim, Y. (2013). Understanding consumers' responses toward social media advertising and purchase intention toward luxury products. *Journal of Global Fashion Marketing*, *4*(3), 158-174.
10. Clapp, J. and Fuchs, D.A.(2009). Corporate power in global agrifood governance: lessons Learned. In Clapp, J. and Fuchs, D.A. (Eds) *Corporate power in global agrifood governance* (pp.285-297). MIT Press.
11. Compton, J., Wiggins, S. and Keats, S. (2010). Impact of the global food crisis on the poor: what is the evidence. *London, ODI*, *99*, p.99.
12. Defra (2018) Food Statistics Pocketbook: Compilation of food statistics. https://www.gov.uk/government/collections/food-statistics-pocketbook
13. Defra (2019) Agriculture in the United Kingdom 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/848641/AUK_2018_09jul19a.pdf
14. D'Odorico, P., Carr, J.A., Laio, F., Ridolfi, L. and Vandoni, S. (2014). Feeding humanity through global food trade. *Earth's Future*, *2*(9), 458-469.
15. Duckett, D.G., McKee, A.J., Sutherland, L.A., Kyle, C., Boden, L.A., Auty, H., Bessell, P.R. and McKendrick, I.J. (2017). Scenario planning as communicative action: Lessons from participatory exercises conducted for the Scottish livestock industry. *Technological Forecasting and Social Change*, *114*, 138-151.
16. Ehrenfeld, J.M. (2017). Wannacry, cybersecurity and health information technology: A time to act. *Journal of medical systems*, *41*(7), p.104.
17. Foster, M.J. (1993). Scenario planning for small businesses. *Long Range Planning*, *26*(1), 123-129.
18. Fraser, E.D., Mabee, W. and Figge, F. (2005). A framework for assessing the vulnerability of food systems to future shocks. *Futures*, *37*(6), 465-479.
19. Godet, M. (2000). How to be rigorous with scenario planning. *foresight*, *2*(1), 5-9.

20. Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M. and Toulmin, C. (2010). Food security: the challenge of feeding 9 billion people. *Science*, p.1185383.
21. Gramberger, M., Zellmer, K., Kok, K. and Metzger, M.J. (2015). Stakeholder integrated research (STIR): a new approach tested in climate change adaptation research. *Climatic change*, *128*(3-4), 201-214.
22. *The Guardian* (2020) 'Coronavirus measures could cause global food shortage UN warns.' Harvey, F. https://www.theguardian.com/global-development/2020/mar/26/coronavirus-measures-could-cause-global-food-shortage-un-warns (accessed 26/03/20)
23. Headey, D. (2011). Rethinking the global food crisis: The role of trade shocks. *Food Policy*, *36*(2), 136-146.
24. Hertel, T.W. (2011). The global supply and demand for agricultural land in 2050: A perfect storm in the making? *American Journal of Agricultural Economics*, *93*(2), 259-275.
25. Gandino, F., Montrucchio, B., Rebaudengo, M. and Sanchez, E.R. (2009). On improving automation by integrating RFID in the traceability management of the agri-food sector. *IEEE Transactions on Industrial Electronics*, *56*(7), 2357-2365.
26. Gebbers, R. and Adamchuk, V.I. (2010). Precision agriculture and food security. *Science*, *327*(5967), 828-831.
27. Goulson, D., (2010). *Bumblebees: behaviour, ecology, and conservation*. Oxford University Press on Demand (Chapter 1).
28. Hooper, D.U., Chapin, F.S., Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S. and Schmid, B. (2005). Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological monographs*, *75*(1), 3-35.
29. Ilyukhin, S.V., Haley, T.A. and Singh, R.K. (2001). A survey of automation practices in the food industry. *Food Control*, *12*(5), 285-296.
30. Jacob, C., Mathiasen, L. and Powell, D. (2010). Designing effective messages for microbial food safety hazards. *Food Control*, *21*(1), 1-6.
31. Jagosh, J., Macaulay, A.C., Pluye, P., Salsberg, J., Bush, P.L., Henderson, J., Sirett, E., Wong, G., Cargo, M., Herbert, C.P. and Seifer, S.D. (2012). Uncovering the benefits of participatory research: implications of a realist review for health research and practice. *The Milbank Quarterly*, *90*(2), 311-346.
32. Kent, C., Pope, E., Thompson, V., Lewis, K., Scaife, A.A., Dunstone, N. (2017). Using climate model simulations to assess the current climate risk to maize production. Environmental Research Letters 12. doi:10.1088/1748-9326/aa6cb9
33. Kondo, N. (2010). Automation on fruit and vegetable grading system and food traceability. *Trends in Food Science & Technology*, *21*(3), 145-152.
34. Lunt, T., Jones, A.W., Mulhern, W.S., Lezaks, D.P. and Jahn, M.M. (2016). Vulnerabilities to agricultural production shocks: An extreme, plausible scenario for assessment of risk for the insurance sector. *Climate Risk Management*, *13*, 1-9.
35. Mangold, W.G. and Faulds, D.J. (2009). Social media: The new hybrid element of the promotion mix. *Business horizons*, *52*(4), 357-365.
36. Manning, L. and Baines, R.N. (2004). Globalisation: a study of the poultry-meat supply chain. *British Food Journal*, *106*(10/11), 819-836.
37. Margosian, M.L., Garrett, K.A., Hutchinson, J.S. and With, K.A. (2009). Connectivity of the American agricultural landscape: assessing the national risk of crop pest and disease spread. *BioScience*, *59*(2), 141-151.
38. *The Guardian* (2020) 'The Covid-19 crisis is a chance to do capitalism differently.' Mazzucato, M. https://www.theguardian.com/commentisfree/2020/mar/18/the-covid-19-crisis-is-a-chance-to-do-capitalism-differently (accessed 18/03/2020)
39. McKenzie, L.W. (1953). Specialisation and efficiency in world production. *The Review of Economic Studies*, *21*(3), 165-180.

40. McCluskey, J. and Swinnen, J. (2011). The media and food-risk perceptions: Science & Society Series on Food and Science. *EMBO reports*, *12*(7), 624-629.
41. McMichael, P. (2009). The world food crisis in historical perspective. *Monthly Review*, *61*(3), p.32.
42. Mellmann, A., Harmsen, D., Cummings, C.A., Zentz, E.B., Leopold, S.R., Rico, A., Prior, K., Szczepanowski, R., Ji, Y., Zhang, W. and McLaughlin, S.F. (2011). Prospective genomic characterization of the German enterohemorrhagic Escherichia coli O104: H4 outbreak by rapid next generation sequencing technology. *PloS one*, *6*(7), p.e22751.
43. Naylor, R. (2011). Expanding the boundaries of agricultural development. *Food Security*, *3*(2), p.233.
44. *Independent* (2016) 'Demand for avocados destroying Mexico's pine forests.' Nelson, K. https://www.independent.co.uk/news/uk/home-news/avocados-deforestation-demand-price-rise-destroy-mexico-pine-forests-a7182571.html (accessed 21/01/2018).
45. Öckinger, E. and Smith, H.G. (2007). Semi-natural grasslands as population sources for pollinating insects in agricultural landscapes. *Journal of applied ecology*, *44*(1), 50-59.
46. Perrin, A. (2015). Social media usage: 2005-2015.
47. Piesse, J. and Thirtle, C. (2009). Three bubbles and a panic: An explanatory review of recent food commodity price events. *Food policy*, *34*(2), 119-129.
48. Pingali, P. (2007). Westernization of Asian diets and the transformation of food systems: Implications for research and policy. *Food policy*, *32*(3), 281-298.
49. Porkka, M., Kummu, M., Siebert, S. and Varis, O. (2013). From food insufficiency towards trade dependency: a historical analysis of global food availability. *PloS one*, *8*(12), p.e82714.
50. Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O. and Kunin, W.E. (2010). Global pollinator declines: trends, impacts and drivers. *Trends in ecology & evolution*, *25*(6), 345-353.
51. Puma, M.J., Bose, S., Chon, S.Y. and Cook, B.I. (2015). Assessing the evolving fragility of the global food system. *Environmental Research Letters*, *10*(2), p.024007.
52. Ratnadass, A., Fernandes, P., Avelino, J. and Habib, R. (2012). Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review. *Agronomy for sustainable development*, *32*(1), 273-303.
53. Redmond, E.C. and Griffith, C.J. (2006). Assessment of consumer food safety education provided by local authorities in the UK. *British Food Journal*, *108*(9), 732-752.
54. Reed, M.S. (2008). Stakeholder participation for environmental management: a literature review. *Biological conservation*, *141*(10), 2417-2431.
55. Richardson, K.J., Lewis, K.H., Krishnamurthy, P.K., Kent, C., Wiltshire, A.J., Hanlon, H.M. (2018). Food security outcomes under a changing climate: impacts of mitigation and adaptation on vulnerability to food insecurity.
56. Rosenzweig, Cynthia; Iglesius, Ana; Yang, X. B.; Epstein, Paul R.; and Chivian, Eric. (2001) "Climate change and extreme weather events - Implications for food production, plant diseases, and pests". NASA Publications. 24.
57. *The Guardian* (2020) 'Coronavirus pandemic has delivered the fastest deepest economic shock in history.' Roubini, N. https://www.theguardian.com/business/2020/mar/25/coronavirus-pandemic-has-delivered-the-fastest-deepest-economic-shock-in-history (accessed 26/03/20).
58. Rounsevell, M.D. and Metzger, M.J. (2010). Developing qualitative scenario storylines for environmental change assessment. *Wiley Interdisciplinary Reviews: Climate Change*, *1*(4), 606-619.
59. Rotz, S. and Fraser, E.D. (2015). Resilience and the industrial food system: Analyzing the impacts of agricultural industrialization on food system vulnerability. *Journal of Environmental Studies and Sciences*, *5*(3), 459-473.

60. Rutsaert, P., Regan, Á., Pieniak, Z., McConnon, Á., Moss, A., Wall, P. and Verbeke, W. (2013). The use of social media in food risk and benefit communication. *Trends in Food Science & Technology*, *30*(1), 84-91.
61. Shan, L., Regan, Á., De Brún, A., Barnett, J., van der Sanden, M.C., Wall, P. and McConnon, Á. (2014). Food crisis coverage by social and traditional media: A case study of the 2008 Irish dioxin crisis. *Public Understanding of Science*, *23*(8), 911-928.
62. Schoemaker, P.J. (1991). When and how to use scenario planning: a heuristic approach with illustration. *Journal of forecasting*, *10*(6), 549-564.
63. Schoemaker, P.J. (1995). Scenario planning: a tool for strategic thinking. *Sloan management review*, *36*(2), 25-50.
64. Shumeta, Z. (2010). Avocado production and marketing in Southwestern Ethiopia. *Trends in Agricultural Economics*, *3*(4), 190-206.
65. Smithers, J. and Johnson, P. (2004). The dynamics of family farming in North Huron county, Ontario. Part I. Development trajectories. *Canadian Geographer/Le Géographe canadien*, *48*(2), 191-208.
66. *The Telegraph*. (2018) 'Supermarket shoppers face empty shelved amid delivery chaos and panic buying.' Spary S. https://www.telegraph.co.uk/news/2018/03/01/supermarket-shoppers-face-empty-shelves-amid-delivery-chaos/ (accessed 04 March 2018).
67. Tadasse, G., Algieri, B., Kalkuhl, M. and von Braun, J. (2016). Drivers and triggers of international food price spikes and volatility. In *Food Price Volatility and Its Implications for Food Security and Policy* (59-82). Springer, Cham.
68. Vellakkal, S., Fledderjohann, J., Basu, S., Agrawal, S., Ebrahim, S., Campbell, O., Doyle, P. and Stuckler, D. (2015). Food price spikes are associated with increased malnutrition among children in Andhra Pradesh, India. *The Journal of nutrition*, *145*(8), 1942-1949.
69. von Braun, J. and Tadasse, G. (2012). Global food price volatility and spikes: an overview of costs, causes, and solutions.
70. Taleb, N.N. (2007). *The black swan: The impact of the highly improbable* (Vol. 2). Random house.
71. Tian, Y. and Robinson, J.D.(2008). Media use and health information seeking: An empirical test of complementarity theory. *Health Communication*, *23*(2), 184-190.
72. Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R. and Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, *418*(6898), p.671.
73. Vidal, L., Ares, G., Machín, L. and Jaeger, S.R. (2015). Using Twitter data for food-related consumer research: A case study on "what people say when tweeting about different eating situations". *Food Quality and Preference*, *45*, 58-69.
74. Verbeke, W. (2013). Europe's horsemeat scandal is unfortunate, but it is not a full blown crisis. In LSE EUROPP Blog. London, UK: London School of Economics and Political Science.
75. Weis, T. (2010). The accelerating biophysical contradictions of industrial capitalist agriculture. *Journal of agrarian change*, *10*(3), 315-341.
76. Wheeler, T. and Von Braun, J. (2013). Climate change impacts on global food security. *Science*, *341*(6145), 508-513.
77. Young, O.R., Berkhout, F., Gallopin, G.C., Janssen, M.A., Ostrom, E. and Van der Leeuw, S. (2006). The globalization of socio-ecological systems: an agenda for scientific research. *Global Environmental Change*, *16*(3), 304-316.

	Scenario 1- Technology shock *cyber attack*	Scenario 2- Financial shock *speculation in food*	Scenario 3- Weather shock *drought*	Scenario 4- Biological shock *pest/pathogen*
High connectivity	Computerised systems are integral to the production, distribution and supply of food.	Perceived health benefits of goods are transmitted rapidly via social media. Individuals and firms from across the globe speculate in food production.	Processing industries across the globe reliant on imported raw commodities from a limited number of countries.	Farmers across the globe buy in livestock feed made from soybean produced in South America.
Low diversity	There are a reduced number of suppliers, and a high dependence on automated technology. Less need for food storage as automation increases efficiency.	Investment boosts the production of a limited number of 'economically attractive' crops.	Some poorer economies significantly dependent on export revenue of one or few crops. Many local livelihoods dependent upon high yields.	Livestock feed market highly dependent upon the one crop variety, its success makes other cultivars superfluous/ uncommon.
Social/economic instability	Reduced food availability lead to price spikes. Panic buying and shortages lead to civil unrest.	Volatility in prices as investors move in and out of market impacts farmers and consumers.	Local livelihoods lost and civil unrest ensues due to increased poverty and economic downturn.	Meat prices spike, concerns over food shortages cause panic buying, escalated by media and social media.
Environmental harm		Reduced habitat heterogeneity and intensive farming causes environmental degradation.	New land brought into production to fill supply gap resulting in a loss of natural areas.	Deforestation of new areas to create land for the production of animal feed.
Food loss/waste	Food that cannot be transported from farm to consumer spoils creating waste disposal issues.			Feedstock shortages lead to premature culling of livestock and diversion of food waste to animal feed.

Table 1. A summary of key themes that featured across the four developed scenarios. System characteristics describe the pre-shock world and trends within food systems whilst the shock consequences detail the aftermath of the shocks, showing themes that occurred in two or more of the scenarios.

Highlights

- Stakeholders can valuably facilitate the exploration of future shocks and impacts
- Connectivity in food systems can increase volatility and vulnerability to shocks
- Loss of food system diversity exposed as another potential source of weakness
- Social media is increasingly important in shaping attitudes/ behaviours towards food
- Increasing automation within food systems may create new sources of shock

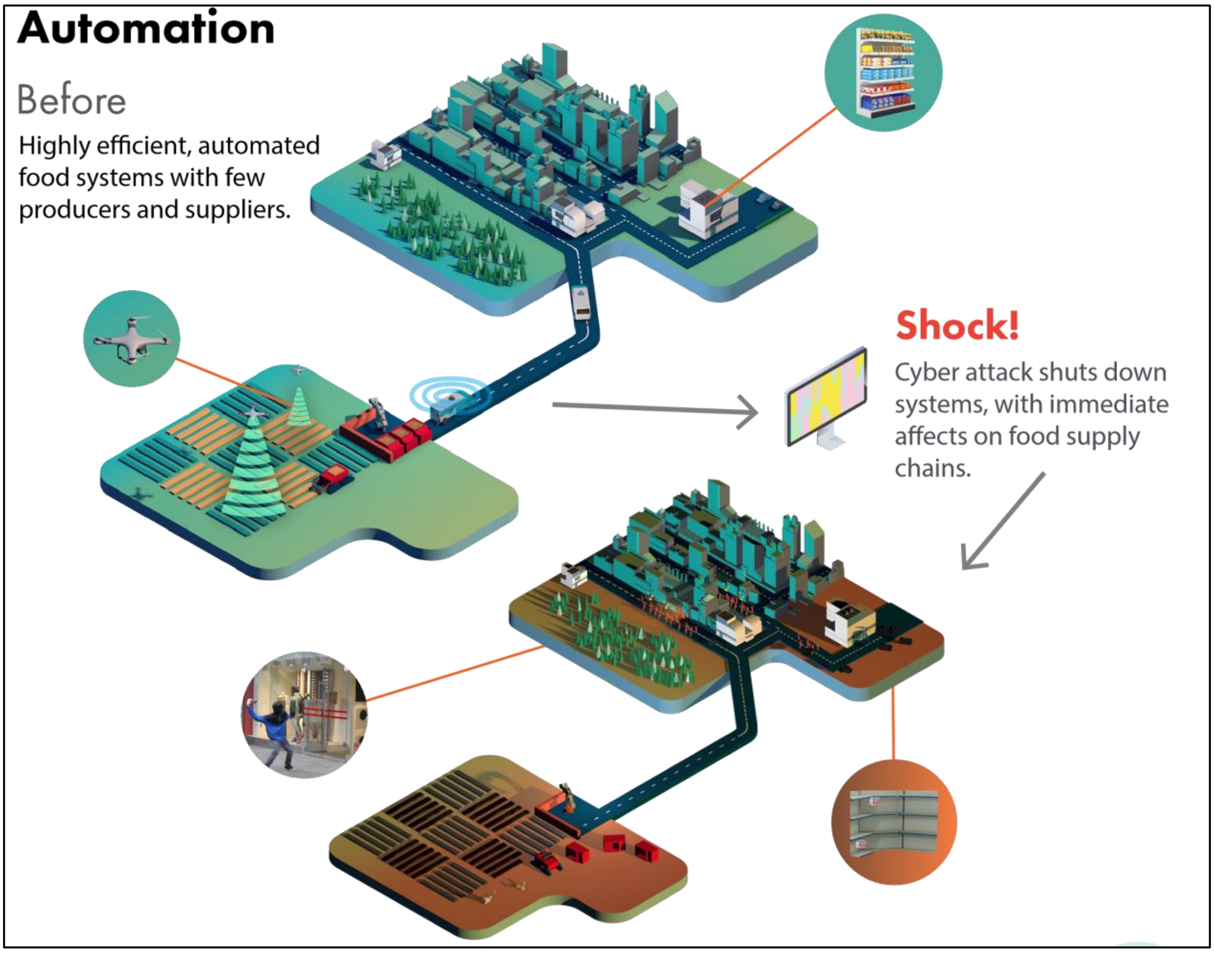

Figure 1. ***Driverless trucks break down. Automated food production systems are developed including driverless tractors and lorries that are subject to technological failures when a cyber-attack occurs.***

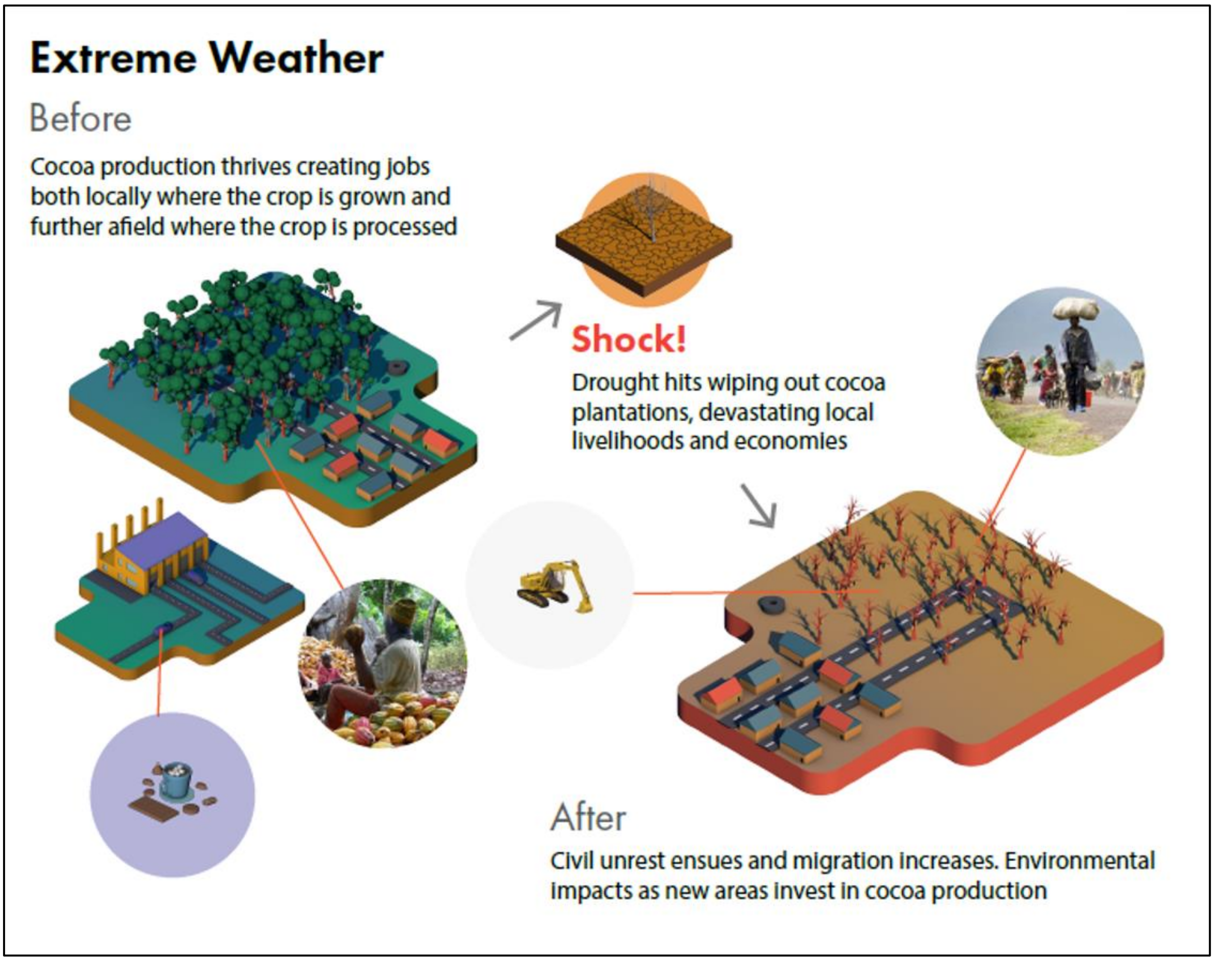

Figure 2. ***Drought causes civil unrest in a developing economy highly dependent on one crop. Processing industries in many disparate countries are affected by a shortage in a key commodity and shifts in land use occur as new regions seek to meet supply/demand.***

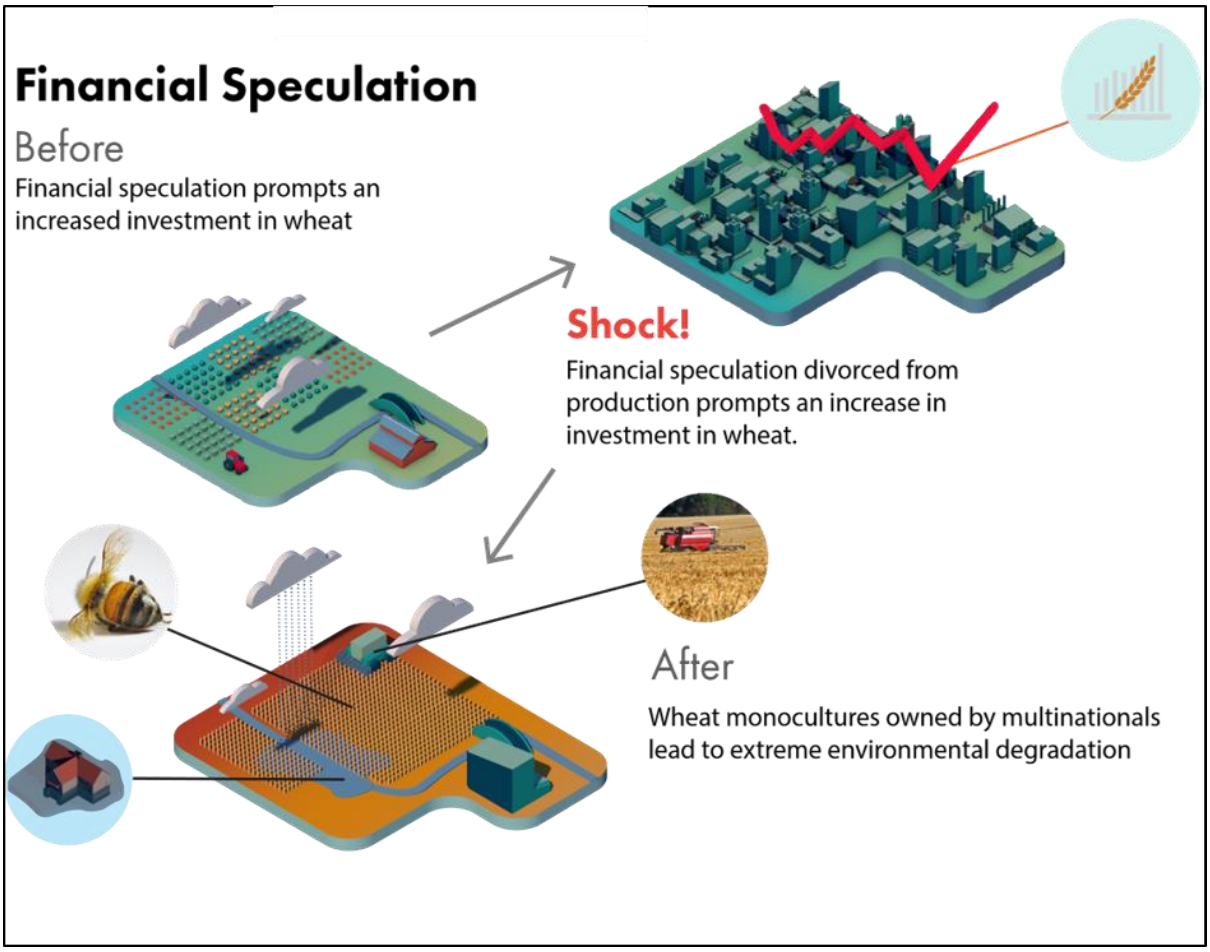

Figure 3. ***Financial speculation spurred on by social media trends prompts an increased investment food production. High potential profits increases the number of multinational companies and reduces the number of small farms. Monocultures and intensive farming lead to environmental degradation.***

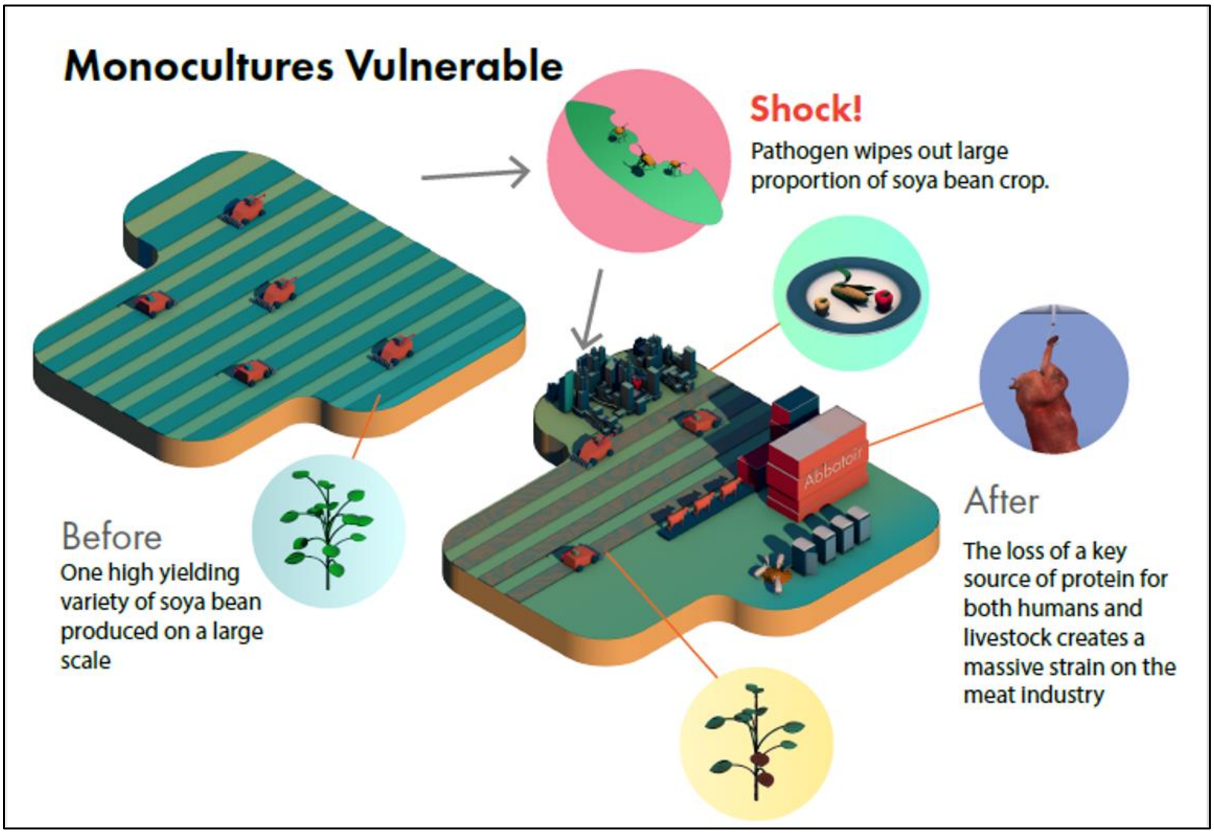

Figure 4. S*oya bean exports obliterated by emerging pathogens. The loss of a key source of protein for both humans and livestock creates a massive strain on the meat industry resulting in increased vegetarianism.*

Appendix A

Short Scenarios/Headlines

1. **Beyonce tweets about eronia berries and how they helped her post-baby body recovery. Leads to price spike and speculation.**
2. **Driverless trucks fall sick. Automated food production systems are developed including driverless tractors and lorries. This is then subject to a cyber attack.**
3. Bee-less in Seattle. Reduced biodiversity and continued environmental degradation leads to total extinction of bees. The resulting loss of pollination leads to food shortages e.g. potatoes, soft fruits, tomatoes etc. This has knock on nutritional effects for the human population and leads to a resurgence in old diseases and the development of new diseases.
4. War causes problems. Conflict in a bread-basket and/or transport hub state affects food production, migration and increases global competition for the affected commodities/products.
5. **Chock Horror! Drought causes civil unrest in Africa's west coast. This shuts down 2/3 of the worlds cocoa supply. There is a price spike in chocolate. There are shifts in land use. Mondelez share price collapses.**
6. World has gone mad. We have escalated conflict between North Korea and the US which results in nuclear action and contamination of most of the US and China, significantly reducing food production. America goes hungry. Rice production in Asia is decimated. There are repercussions for global trade.
7. Nuclear winter of discontent. North Korea launches nuclear attack on China, polluting agricultural land and rivers, ultimately impacting marine life as well as killing lots of people. There are enormous political and economic consequences.
8. Extreme weather events. Globally correlated, impacts people on the move. Disturbed rainfall patterns, influences by climate change, lead to prolonged drought across central Africa and humanitarian crisis over several years. Migration issues follow. Climate refugees to Europe. Associated drought elsewhere (e.g. India, Australia) leads to staple crop price hikes.

9. Gulf Stream moves south. Lack of genetic diversity in crops and livestock leaves UK agriculture increasingly vulnerable. Leads to failing farms, higher imports and reduced production.
10. Stateside goes darkside. Super volcano in Yellowstone wipes out North America bread basket. Ash cloud cuts food production across the world.
11. UK farmers go to the wall as Brexit hits cap and trade. Concentration of production and processing leads to abandoned uplands and loss of rural economy.
12. Growing income inequality in the UK leads to more food poverty and instability leading to civil unrest and conflict. Bread riots trigger public consciousness of food poverty.
13. Brexit economics lead to vast shortage in labour. No one left to harvest produce and serve out food. Britain no longer produces food.
14. Financial speculation, divorced from production, leads to price spikes unconnected or uncontested in terms of actual production, harvesting or manufacturing. This produces and inauthentic economic signal to those connected with the industry.
15. **Argentinian soy bean exports obliterated by emerging pathogens. Increased pressure on amazon deforestation for grazing. Global beef, dairy and poultry industry dramatically affected by price hikes. Animals culled early. Insurance claims increase. Dietary knock on effects. Enforced vegetarianism 6 days a week. Stock collapse for the associated firms. Financial instability.**
16. New strain of bird flu transmissible to humans devastates global poultry firms. There is loss of public trust in regulating regimes and political leadership as weak hygiene checks blamed. Black market in Tamiflu as most vulnerable are hardest hit and millions of jobs are lost worldwide.
17. Don’t count your chickens! Avian flu pandemic wipes out chicken production in Southeast Asia and evolves to infect humans affecting production, consumption and health.