UK Food and nutrition security during and after the COVID-19 pandemic: Project Report and Recommendations

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Notes on the research: As the pandemic unfolded, there was a substantial amount of information produced online and in the media, much of which was not peer reviewed hence of variable quality and utility. Where possible the details contained in the individual project reports using such sources have been selected based on assessing source quality. However, the pandemic has been a rapidly evolving situation and some references may have become outdated after use in the duration of the project. We also highlight that it has not always been possible to disentangle COVID-19, EU Exit and other drivers impacting on the UK's food and nutrition security.

Foreword

This is an interesting read for anyone keen to explore the resilience of our food system. It asks to what extent the Covid pandemic created a "teachable moment" for policy makers – a moment which revealed the failings of our food system and spurred commitment to tackle them. Alas, it concludes it was not.

It lays out the evidence demonstrating that the Covid shock was a demand shock, unlike many food system shocks in recent history which have affected supply. In contrast to past shocks, it did not trigger a wave of export bans or other interventions to protect food supply – though these were expected in the early stages of the pandemic. A few weeks after the first lockdown, while the supply chain adjusted to the rapid shift in demand patterns in the UK, shelves continued to be stacked and for the most part, no major questions have been asked about whether our supply chains are resilient enough. Instead, the economic and social impact of the pandemic affected purchasing power, purchasing patterns and access to food. It taught us about the precarious nature of livelihoods for many in the UK, the gaps in our social safety nets and it revealed, in the cold mortality and hospitalisation statistics, the threat which our dietary health poses to our very survival. While this was not about food system resilience per se, it was undoubtedly a teachable moment for policy makers.

And I would argue it was a teachable moment for us citizens. It made us realise that we are dependent on a food system which we have never had reason to question; where a multitude of choice, from a multitude of countries is available in multiple places close to our home. For a few weeks just getting hold of some foods became a big deal for many and momentarily it made us stop and consider where our food comes from.

But neither of these observations are sufficient to deal with the risks we face. The report goes on to explain in some detail the increasing evidence of "threat multipliers" – to which, of course, the food system is a massive contributor. It explains why these look set to be an increasingly important feature of our food supply chains in future. I would argue we're seeing evidence of these right now in the UK. Food prices are rising from a complicated picture of gas price rises (which in turn affected CO2 supply which is used in food production), import costs and global food price rises (linked to some extent to the pandemic), all of which are affecting what people can afford to buy in the UK. Here, we are tracking the situation on an ongoing basis because of the material impact prices have on people's diets. The deepening climate crisis combined with the world's dependence on a few major staples produced in a few countries mean these threats are mounting.

Importantly the report explores what a more resilient food system would look like and what implications such a system might have for how we use our land in the UK. In doing so it explains that shifting demand in favour of healthy and sustainable diets is a vital condition for successfully shifting production in favour of reducing global temperatures and increasing biodiversity – both of which are vital if we are to reduce the threats which our supply chains face. It explains that a more resilient food system is both necessary and possible, but it requires visionary leadership and institutional coherence. The National Food Strategy was developed during the pandemic and offers a blueprint for a better future. The real test of whether the pandemic was a teachable moment for our future food system, is whether policy makers follow it.

Anna Taylor
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Summary

This report presents the findings of a study on the impacts of COVID-19 on the UK's food and nutrition security and what lessons can be learned for the future in respect of transformation of the food system to be resilient and sustainable. The food system underpins society and economies and is being impacted by COVID-19 as well as becoming increasingly at risk from the consequences of threat multipliers such as climate change, biodiversity loss and ecosystem degradation. Of increasing concern are the risks of multiple coinciding events that will stress test the food system beyond anything recently experienced. Such multiple events could be climate extremes and economic downturns, both having differentiated impacts on production, availability and food prices. These potentially compounding risks and associated requirements for complex synergistic solutions to meet multiple objectives for the food system need to be set in context with a growing demand from a more numerous and affluent global population and finite production resources. The food system also accounts for approximately 34% of global greenhouse gas emissions, hence there is need for immediate mitigation.

A key question is therefore how we define food system resilience and whether it will be resilient to emerging pressures. To inform discussion on this, we present an overview of the COVID-19 pandemic impacts and identify what lessons can be learned in respect of informing food system transformation to achieve multiple objectives of improved diet and human health, economic prosperity and environmental sustainability in order for the food system to become resilient.

The research considered how the pandemic affected the strengths and weaknesses of the food system and how this relates to its resilience to plausible future challenges. The coinciding of the pandemic and Brexit made it difficult to disentangle specific effects of each event on the food system, which illustrates the potential for compounding multiple risks to food and nutrition security. We provide some recommendations on what needs to be done to enable a sustainable and resilient system that is good for human and environmental health.

The findings are presented taking an overview perspective of the pandemic and in the context of the need to transform the food system to align with changes in trade, land use and management and supply chain processes to meet multiple objectives including: achieving net zero emissions; improving human health through better diets; and promoting a resilient, sustainable healthy environment better able to provide ecosystem services.

The key message from this research, in light of lessons learned from the COVID-19 pandemic, is the need for preparation and contingency planning with national food system strategies and internationally agreed measures to protect food and nutrition security. Fundamentally, prevention, in the form of reducing climate risks through deep and rapid mitigation and well-resourced support for adaptation in the food system, integrated with the reversal of environmental damage through sustainable production methods and ecosystem restoration will help progress towards protecting food and nutrition security against future risks.

Key findings:

- Concerns at the start of the pandemic of very severe impacts on the food system and consequences on the UK's food and nutritional security did not materialise, in respect of production losses causing shortages and rapid increase in prices.
- Based on the United Nations Food and Agricultural Organisation's definitions, **the UK did not become food insecure** during the pandemic, **however,** economic and physical access difficulties by those on low incomes and reduced mobility meant increased hardship and increased risk of food and nutrition insecurity.
- **Food and nutrition insecurity grew in the UK during the pandemic**. The impacts highlighted and exacerbated existing food and nutrition security inequalities in the UK and globally.
    - The Food Foundation's most recent reports show that the percentage of food insecure adults was 7.6% pre-COVID, rising to 9.7% at the start of the pandemic, increasing further 9.9% in the period February to July 2021, affecting 5.2 million adults.
    - The number of children living in households experiencing food insecurity reached 2.5 million (14% of households, February to July 2021), a 27% increase from pre-COVID (2018, 11.5%).
    - Healthy diets have a socio-economic dimension that operate independently of technical aspects of food production, processing and supply chains. Reduced incomes and the lack of provision of school meals during lockdowns exacerbated existing inequalities and caused real hardship.
    - Improvements to income support to reduce impacts on the most vulnerable do not guarantee food and nutrition security improvements if access to unhealthy food environments increases. Additional support through education is required to help improve food utilisation.
    - The use of food banks increased. As of May 2021, the number of people receiving three days' worth of emergency food by Trussell Trust foodbanks increased from 1.6 million in 2018/19 to 2.5 million in 2020/21 (Statista 2021).
    - The third sector provided an essential role in filling the social support gap, despite severe restrictions on their own ability to operate and raise funds.
    - Local Authorities have also played an important role in ensuring charitable food provision for the vulnerable during the crisis.
- In 2020 and early 2021 **the COVID-19 pandemic primarily caused a demand-side economic shock to the food system**, both in the UK and globally, with a disproportionately larger economic and physical access impact on vulnerable groups, leading to an increase in food poverty rather than a supply-side production shock resulting in empty supermarket shelves.
    - Impacts have mostly been the result of demand contractions.
    - There were shortages of some food types caused by disruptions to processing, storage and transportation.

- Globally food production and availability before the pandemic was marginally above long-term average with productivity in 2020 and 2021 being good, meaning shortages were limited.

- **Food system logistics globally continued to function adequately during the pandemic disruptions**, but the limits of its resilience to plausible future threats were exposed. The infrastructure coped up to a point with the pandemic shock but highlighted weaknesses regarding current human health demands in the face of pre-existing poor diets, and vulnerable to future environmental sustainability needs in respect of climate change, biodiversity loss and ecosystem degradation challenges.
  - Vulnerabilities of the 'Just in Time' supply chain approach to shocks were exposed.
  - 'Breadbasket' production areas are vulnerable to climate change impacts and pest and disease outbreaks. Diversification in crop types grown and localisation of production and markets will reduce risks.
  - The pandemic impact on the food system operation was primarily through effects on people, able to be offset by fiscal measures such as furlough schemes and public health measures. Future challenges will impact both people and the environment*, risking reduced food production, shortages and higher prices.
  - * In 2020 the UK experienced large reductions in primary production of cereals due to severe weather.
- **International trade of food broadly remained effective** despite some regions having been affected by supply-chain constraints and some markets by significant shortages and price rises.
  - The UK food system was already in a state of readjustment prior to the pandemic, due to EU exit; moreover, the ramifications of the UK's withdrawal from the EU are ongoing.
  - Globally, impacts have mostly resulted from recalibrations in demand. Food- and agriculture-related trade measures implemented by individual countries have not been as severe or harmful as those adopted during the global food price crises of 2007–08 and 2010–12.
  - The UK must position itself both internationally and domestically in the vanguard of supporting and enabling post-COVID food systems that forestall short-term food insecurity concerns and that promote long-term nutritional, livelihood, and environmental security.
- **UK food prices have remained relatively stable.** Prices rose during the first national lockdown but fell for much of the rest of 2020, but in 2021 UK prices have risen steadily, reflecting global trends, which have been increasing consistently since May 2020 despite generally plentiful food supplies.
  - Globally, prices are likely to increase in 2022 due to rising inputs costs, particularly for energy.
- **The food system as it currently operates is subject to market forces that do not fully account for the costs to society** of poor health outcomes due to poor diet and utilisation, nor environmental damage from unsustainable production practices. The implication is that we do not value human and environmental health outcomes appropriately in the economics of the food system.

- The UK and elsewhere is experiencing large increases in the levels of obesity, costing the National Health Service about £5 billion per year, but with wider social costs of c. £27 billion.
- **The food system accounts for c. 34% of global greenhouse gas emissions.** In 2015, food-system emissions amounted to 18 Gt CO_2 equivalent per year globally, representing 34% of total GHG emissions. The largest contribution came from agriculture and land use/land-use change activities (71%), with the remaining were from supply chain activities: retail, transport, consumption, fuel production, waste management, industrial processes and packaging (Crippa et al 2021). Hence deep and rapid mitigation changes are needed.
- Soil health is in decline whilst ground water resources are being depleted worldwide, threatening food production.

- **There is a risk that the limited impact of the pandemic on the food system could lead to complacency** through the misleading conclusion that the system is resilient. This potentially endangers the effective transformation that is required to increase food and nutrition security and tackle the climate emergency.
- **Future climate and environmental degradation shocks are likely to affect production**, with subsequent food shortages leading to increased economic access difficulties for those on low incomes.
  - The pandemic has, and likely climate impacts will, exacerbate existing inequalities in the food system.
- The project has developed **four plausible UK focussed scenarios** with a panel of experts to explore possible pathways and consequences on UK food and nutrition security of multiple drivers within a global context.
- **A UK spatial analysis** using a land use allocation model and the four plausible scenarios indicates there are important trade-offs between land use and food production in the UK in response to drives to increased self-reliance, the ability to increase agricultural yields, and plans to increase tree cover, bioenergy crops, or bespoke biodiversity areas on farms. The analyses compared changes related to food demand, food supply, and regulation, and also included the effects on the demand and supply of wood.
  - Increasing the level of food imports creates greater flexibility for UK land use decisions and was associated with positive impacts on UK soil functions. However, there are important ethical questions when transposing increased food production to other countries on the capacity of those countries to reduce greenhouse gas emissions, prevent deforestation, and enhance biodiversity. There is a need to undertake global life cycle assessments of such effects.
  - The use of agricultural innovation and improved management to steadily increase yields per hectare creates opportunities to enable both increased food security, increased carbon sequestration, and the release of areas for biodiversity enhancement.
  - Conversely, a reduction in net imports reduces the availability of UK agricultural land for other purposes, hence greater food self-reliance in the UK is likely to lead to major economic and environmental trade-offs either in terms of food security or the availability of land for expanding tree cover, production of biofuels or increases in land area under protected status.

- Widespread use of bioenergy crops on crop land and constraints of fertilizer use and the assumed reductions in UK crop yields below current levels were found to have significant negative effects on the capacity of the UK to maintain food security.
- If a UK food production policy uses greener methods where yield increases over currently conventional practices are not expected, then reduced meat consumption per capita can be useful in matching food demand and supply.
- The spatial model used assumed similar land use policies in the UK and the EU. Following Brexit, it may be increasingly important to have land use models which can study the effect of different land use policies in the UK and the EU.

- **There is an interesting contrast between those drivers that enable and those that reduce flexibility in land use.** For example, increased agricultural yields can enable increased tree cover, whereas setting tree cover targets does not directly lead to increased agricultural yields. Whilst targets specifying a certain area of land for a specific use have a role, those targets need to be set with an understanding of the potential effects on food security and consider land capability for multiple objectives.
- **Soil function indicators mapping** has highlighted how land use changes under different scenarios either positively or negatively impact key environmental benefits supported by soil (carbon storage, primary productivity, water supply, nutrient availability and pollination).
- There are positive opportunities for land use changes to achieve healthier diets.
  - There are sufficient land resources available in the UK to enable food production that aligns with a healthy diet.
  - Changes in UK land use and food production to achieve a healthy diet can also reduce the environmental footprint.
  - Changes in land use and types of food produced needed for human and environmental health will require substantial changes to the food system in respect of consumer behaviour driving market demand.
  - Transformation of food production will have consequences on rural communities, socio-economics and business practices, with both risks and opportunities.
- **There are good opportunities to align production of food groups for healthy diets.**
  - Recommendations exist on the types and proportions of foods and drinks needed for a healthy balanced diet, such as Public Health England's Eatwell Guide, that can be used to identify opportunities for changes in land use and food production.
  - Moving from current to the recommended patterns in the Eatwell Guide requires more energy to be derived from carbohydrate and protein, and less from fat. The proportion of simple sugars in consumed carbohydrates should be halved, salt consumption should be reduced, and fibre consumption increased.
  - A move to healthier diets is expected to increase the demand for milling wheat, vegetables and fruits, with declines for beef, pig meat, sugar, and milk. If these changes occurred, they would affect the level of UK self-reliance for these products.
  - The COVID-19 pandemic has led to a "K" response in the consumption of healthier food: some people have healthier diets; many people have had a less healthy diet. Because

unhealthy food is typically cheaper than healthy food, financial insecurity leads to less healthy diets.

- There are risks and opportunities of aligning food production to demand.
  - To increase production to match demand more closely for those commodities already produced in the UK, while at the same time adjusting to aligned production with diets that are healthier for humans and the environment, will have consequences for land use, farm inputs, and income.
  - Overall, moves towards self-sufficiency, healthy diets, and the reduction of GHG emissions favour reduction in meat and dairy, as well as cereals because of a decline in demand for livestock feed. Potatoes and horticultural crops (fruit and veg) would see substantial increases in production.
  - The combined impact of these changes would be to reduce the demand for land, both pasture and arable (down by as much as 26%) and reduce nitrogen application by up to 23%. Pesticide input would increase substantially (up to 58%) and the shift in commodities would results in increase in income by as much as a 28%.
  - Post-COVID-19 Green Recovery scenarios offer a way forward that tackles climate change and diet related ill-health while also offering greater production efficiency. However, the changes in the livestock and horticulture sector would demand significant structural changes to the UK agri-food system.
- There are positive impacts of adopting agroecological farm practices.
  - Sustainable production of food in the UK requires a transition to agroecological practices where the farmed environment is managed for provision of multiple benefits in terms of both crop production and the environment.
  - Agroecological farming is based on functional biodiversity which is utilised for: a) internal system regulation and increased production efficiency which together reduce reliance on agrochemical inputs, and; b) enhancing resilience through functional redundancy, thereby insuring against future shocks and improving yield stability in the long-term.
  - The capacity for UK farming to benefit from agroecological practices, in terms of long-term sustainability and resilience to future disruption, depends on the extent to which transition is supported following Brexit and in the aftermath of the covid pandemic.
  - A “build back greener” recovery, with incentives for crop diversification, soil health and biodiversity management is most likely to deliver the opportunity to transition to more sustainable agroecological production systems in the UK with the potential to meet demands for a more diverse range of home-grown food products.
- **There are large opportunities to increase UK protein production.** While the UKs food system is legume-dependent, these are not home-grown, Consequently, and in addition to the risks of import dependency, the environmental benefits of home-grown legumes are forfeited.
  - More investment in legume grain processing capacities nationally would also help achieve the commercial of legumes for human consumption. The consumption shift to such legume-based options would also help reduce the direct and indirect costs to national health burdens.

- There is real opportunity to realise more agroecologically-balanced agriculture using legumes for their multifunctional and complex provisions, including the replacement of synthetic nitrogen fertilisers and enhancement of essential soil functions, including resilience I.e. the ability to withstand shocks.
- To enable the potential of legumes, care should be taken to avoid an over-focus on high protein legume grains, as forage legume types delivered have great potential to help ensure greater levels of nutrient use efficiency, and optimised system functions.
- Land use efficiency can also be enabled by forage legumes, as greater levels of production can be enabled in more-permanent grasslands, reducing demand for grains as feed (whether imported or home grown) freeing arable areas for crop diversification, increased levels of biodiversity, and development of greater food (as opposed to feed) production capacity.
- Greater resources use efficiency may also be accommodated for by legume- and non-legume crops through greater uptake and better use of cover crops, especially where these are integrated with other innovations such as no- and minimum-tillage.

There is increasing potential for the use of new technologies, such as Controlled Environment Agriculture and precision agriculture.

- Controlled environment production, such as Vertical Farms, enables the potential to produce food locally in urban areas using renewable energy.
- Facilitates more efficient use of light and nutrient resources, and reduction in loss due to disease.
- This presents opportunities for producing crops sustainably.
- Enables improved and more rapid research on crops, for example accelerated phenotyping.

Will the pandemic drive change?

Arising from these key findings, a fundamental question becomes “has the pandemic been a sufficiently impactful event large enough to drive change in the food system?”. Our conclusion is that it has not, on the basis that supply was maintained and, given food is such an essential part of the economy and always in demand, food businesses have in general remained profitable (with obvious exceptions including those in hospitality, due to change in demand, not supply). However, it has compelled society, the food system stakeholders and governments to re-evaluate what is meant by resilience.

A second following key question thus needs to be asked: “Do we have a false sense of national food and nutrition security?”. There is a substantial risk that the overall conclusion drawn to the first question is that the current structure of the food system is resilient, because it maintained supply and that a sufficiently large enough majority of businesses remained financially viable (indeed for some, profits increased). This risks development of a false sense of security and over-confidence in the ability of the food system to cope with future sporadic, multi-faceted and geographically diverse production-based shocks which may have unpredictable cascading consequences through food price rise impacts and differences in geopolitical responses.

Lessons learned from the COVID-19 pandemic

Whilst the pandemic has affected everyone, it has had differentiated impacts on society and economic sectors. This has been termed the "K" response to the pandemic. In respect of learning from this experience and developing strategies for improving food and nutrition security, in the UK and globally, the key lessons include:

- Prevention is better than cure: the Global Preparedness Monitoring Board estimates the pandemic response costs so far at $11 trillion, with a future loss of $10 trillion in earnings, whereas preparing for a pandemic would have cost the world $5 per person.
- Potential negative effects of the pandemic have been avoided by food trade between countries remaining relatively stable. There is a need to maintain international trade and not impose export restrictions, to maintain the flow of food and materials to enable its production (i.e. fertilisers).
- It is essential to maintain supply-side capabilities when the demand-side is impacted by economic access difficulties, otherwise production shortages will drive price rises compounding economic hardship.
- The pandemic impacted already vulnerable people the most, particularly those on low incomes, women and some ethnic groups who saw further reductions, or those who lost their income source, for example those excluded from the furlough scheme. Government supports schemes helped alleviate the worst of the impacts in respect of reducing economic access issues and hence food and nutrition insecurity, but there remained a heavy reliance on the third sector to provide additional support.
    - The third sector experienced an increase in demand for their services whilst their resources were squeezed by lockdown of normal fundraising activities and social distancing affected operations.
- Policies and financial support can respond at scale and speed when necessary.
- People working in maintaining food security should be counted as essential workers.
- Governmental responses to the pandemic stress tested the reliability of the global food system, revealing the potential for supply disruptions to global trade as border friction increased. In the UK, Brexit compounded border friction in our busiest trade routes. The complexity of the interactions in the system made predictions extremely challenging.

The need for preparation

In respect of developing a food system that will better cope with future shocks and improve resilience for food and nutrition security, the primary lesson from the pandemic is that prevention is better than cure, and that preparation and contingency planning can reduce severity of impacts. Virologists and epidemiologists had for many decades warned that it was a question of *when* a pandemic would occur, not *if*. This prediction certainty implies the expectation that governments and global organisations would be appropriately prepared. This was clearly not the case. There were some capabilities in place, for example a strong foundation on which to develop vaccines to COVID-19 developed by the biological and medical sciences, supported by prior governments and private sector investments. However, few if any governments were ready for the scale of the

pandemic impact on society and its varied economies, or the pace at which the COVID-19 virus spread, indicating a lack of overall contingency planning and ability to put into place pre-prepared measures.

Climate, ecological and other science disciplines have also long warned of the risk due to climate change, biodiversity loss and ecosystem degradation and the risks these individually and collectively pose, yet we continue to increase emission, loose species and destroy habitats. For climate change, biodiversity loss and ecosystem degradation there are substantial risks of crossing critical tolerance thresholds leading to irreversible damage, meaning, unlike COVID-19, there may be no cure. Under such threats, the 'vaccine equivalent' is to mitigate greenhouse gas emissions, enhance biodiversity and restore and protect ecosystems.

The food system has not been stress tested by the pandemic. The primary stress on the food system during the pandemic was a demand side shock. However, climate change, biodiversity loss and ecosystem degradation are likely to cause supply side shocks, for which the food system has not yet been stress tested. When coupled with high demand from a more numerous and affluent global population, potential for increased competition between countries to maintain reserves and plateauing production potential, the food system may become more vulnerable to shocks. This is particularly concerning when simultaneous multiple shocks occur, as increasingly seems likely under climate change.

An opportunity to reflect and adapt

The pandemic is an opportunity to pause and reflect on what society wants from the way our economies are structured and organised. A key part of this is how we build a safe and resilient food system that ends hunger and malnutrition, is equitable, economically viable and improves human and environmental health. Given the scale of transformation needed to achieve these multiple objectives, it is essential to establish *fora* through which a diversity of stakeholders can voice their experience and concerns, to enable meaningful dialogue on developing solutions. This necessitates the opportunity to challenge the power relations in the food system and develop a shared vision of what a sustainable, resilient and equitable food system looks like and how this can be achieved.

The UK has reduced the negative environmental effects in the UK of its demand for food by importing food from other countries. In a similar way it has also reduced its greenhouse gas emissions in part by importing GHG intensive products from other countries. The area of global life cycle assessment and the extent to which the costs of food imports are the responsibility of the importing country are an important area of research.

Looking Forward: The Decade of Change

The United Nations has described this as the Decade of Change in recognition of the challenges society faces in meeting the Sustainable Development Goals in the face of the climate, biodiversity and ecological health crises. At the core of the SDGs is the need to end hunger and achieve food and nutrition security for all people. The actions needed to meet these challenges must be rapid and at scale: reduce greenhouse gas emissions immediately; adopt sustainable environmentally beneficial food production practises; restore degraded ecosystems; align land and marine use for food production, processing and retail with healthy diets; develop safety nets to protect the most vulnerable when shocks occur; internalise the human and environmental costs within the food system.

Contents

Introduction

The COVID-19 pandemic is a major shock to society in terms of health and economy that is affecting both UK and global food and nutrition security (FNS). The global food system provides critical underpinning support for society and represents the clearest connection between human needs and the ability of the environment to provide them. Nearly half of the food we consume in the UK is imported and UK livestock industries rely heavily on feed produced abroad, hence to consider UK food and nutrition security, it is essential to assess the international situation. The pandemic is adding to the 'perfect storm' of threats to society from climate change, biodiversity loss and ecosystem degradation, at a time of considerable change, rising nationalism and breakdown in international collaboration (Rivington et al 2020). In the UK the situation is further complicated due to Brexit.

The pandemic recovery presents opportunities to better align policy responses that improve UK food system resilience, result in healthy diets and contribute to the achievement of net zero emissions and the global Sustainable Development Goals. Resilience theory as it applies to food systems has its origins in ecology and is increasingly formulated as a generic, socio-ecological approach, containing many concepts and ideas, for example Food and Nutrition Security, in an interdisciplinary space. Here, we use the term broadly, following Tendall et al. (2015), to convey our perspective of a complex, whole food system including social, economic and biophysical processes, with a resilient system being one that minimises weaknesses and accentuates capacities while dealing with future uncertainty.

Since this project started the National Food Strategy reports (Dimbleby 2020 and 2021), The Economics of Biodiversity: The Dasgupta Review (Dasgupta 2021) and IPCC 6th Assessment Working Group 1 – The Physical Basis (IPCC 2021) have been published, making clear the need for transformations in the food system, the importance of biodiversity and healthy ecosystems meaning they can function and provide ecosystem services to enable food production, and the current deteriorating state of the climate that risks severe impacts to food and nutrition security. Food systems have the potential to nurture human health and support environmental sustainability; however, it is currently threatening both (Willett and Rockström 2019).

> *"There is a lot of work to do if we are to rebuild a food system that delivers safe, healthy, affordable food to everyone; that is a thriving contributor to our urban and rural economies; that restores and enhances the natural environment for the next generation; that is built upon a resilient, sustainable and humane agriculture sector; and* ***that is robust in the face of future crises****"*
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> (Dimbleby, 2020, National Food Strategy Part One, P.17 [our emphasis]) and goes on to say in Part Two (Dimbleby 2021 P.12):
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> *" it is not possible to build a sustainable, healthy and fair food system by doing business as usual"*

The pandemic recovery will be challenging, but given the additional and mounting climate, biodiversity and ecosystem degradation challenges, it is also an opportunity to rebuild the food system and address wider social justice issues and threats to society.

The complex, inter-related challenges facing the UK food system are:

- There are large social inequalities in economic and physical access that disproportionally negatively impacts the poor.
- The drive for efficiency has resulted in the cheap food paradigm, meaning low-priced but low nutritional quality, but does not account for the cost of poor human health due to diet and environmental degradation.
- There are large inequalities in diet quality and food security, with both under- and malnourished people and others with high energy but low nutrition diets, both leading to different health problems. There is an oversupply of highly processed foods with unnecessary high calorific content but low nutritional value.
- Power relations and governance structures, in respect of who has the greatest influence on how the food system functions, have developed to maintain a business-as-usual approach, rather than a transformative one.
- Supply chains that are vulnerable to interruption.
- An imbalanced land use system that is centred on livestock and cereal production, rather than what is required for a healthy diet. What we produce as food does not align with what we should consume for a healthy diet.

Given the risks and opportunities facing the food system and its complexity, it is essential that research be developed to provide support to strategic decision making on the transformation to meet the multiple objectives of security, human health and environmental sustainability.

About the Project

The "**UK food and nutrition security during and after the COVID-19 pandemic**" project was funded by the UKRI Agile Response fund through support of the Economic and Social Research Council (Grant ES/V004433/1). Details of the overall project objectives and context are available in Rivington et al (2021) and on the website: COVID-19 Food and nutrition security | The James Hutton Institute which contains links to the individual sections detailed here.

Key research objectives:

1. Assess the current response of global food systems.
2. Assess UK food system responses and vulnerabilities.
3. Assess cascading causation of further impacts within a common framework of differing plausible scenarios.
4. Propose alternative agricultural land use, land management and supply / value chain relationships for improved UK self-reliance and long-term environmental sustainability.
5. Identify spatial consequences on the environment of pandemic responses and opportunities for improved food and nutrition security and food system resilience through sustainable agriculture.
6. Review lessons learned from the pandemic for adapting the food system to help achieve climate change and biodiversity goals.

7. Disseminate results and provide recommendations to inform policy development to increase food system resilience.

Objective: Firstly to assess the pandemic impacts on the UK's food and nutrition security and explore future perspectives to provide input to the debate about how the food system may transform. Secondly, to undertake an exploratory assessment of the complex inter-relationships between the many parts of the food system with the aim of highlighting how lessons learned from the pandemic impacts can inform planning for societal and environmental change in ensure the UK's food and nutrition security without offshoring negative consequences.

We present results covering two timeframes: 1. the impact on international trade and national production consequences on the UK's food and nutrition security *during* the pandemic; 2. what this may mean *after* the pandemic in terms of future changes in UK land use and food production consider issues in respect of land use, diet, net zero emissions and environmental health. An overview perspective of the UK's food and nutrition security has been taken.

Part 1 consists of assessments in global trade and literature reviews as information on the impacts became available for the multiple aspects of the food system and society (June 2020 to August 2021). In assessing the future, **Part 2** consisted of the creation of four plausible future UK post-pandemic and Brexit scenarios to 2030, developed using a scenario planning exercise with a diverse panel of experts. These scenarios were then used in three assessments: 1) the relationships between human diet and food production in terms of land use and new technology; 2) the application of a spatial modelling framework to assess land use and environmental health in response to changes in trade; 3) the use of the FeedUs model to assess how the scenarios vary in respect of who the UK trades with how imports and exports may change. A fundamental aspect of the first and second assessments was to consider land capability and primary and secondary food production as the basis to then explore what can change based on biophysical constraints.

The overarching context is to assess what can be learned from the pandemic impacts on the international and UK food systems, the responses to these and what this might tell us in respect of transformation of the food system to improve diet and build resilience to risks from climate change, biodiversity loss and ecosystem degradation.

Defining Food and Nutrition Security

The UN Food and Agriculture Organisation defines food security as '*when all people, at all times, have physical, economic and social access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life'* (FAO, 2009, p. 1). This definition uses key aspects, referred to as the four pillars (or dimensions) of food security (FAO, 2008):

- Availability: This includes the supply side of food production, reserve stocks and net trade.
- Access: The ability of people to access food, separated into:
  - Physical: ability to travel, access shops and markets and store food.
  - Economic: ability to acquire food by purchase or trade.
- Utilisation: How the body utilises nutrients, with sufficient energy and nutrient intake being connected with feeding behaviours, preparation practices, diversity of diet and distribution within households.

- Stability: The stability of the other three pillars, when periods of reduction in them can lead to a deterioration in nutritional status.

For food and nutrition security to be realised, all four pillars must be fulfilled simultaneously. Beyond these pillars, it is also necessary to consider other aspects, including the relationships between diet and health (malnourished or overweight and obesity), and factors that limit or inhibit nutrient uptake. A further set of issues include: the practical, economic and moral dimensions of food waste: over-consumption; and nutritional value loss through conversion of primary production into other food products.

A key concern for food and nutrition security in the UK is the inequalities that the food system causes, and now how the pandemic is accentuating the differentiated impacts between sections of society. A further dimension is the duration of insecurity: whether long-term and / or persistent (chronic insecurity); or short-term and temporary (transitory insecurity).

Defining the Food System

In a simple representation, the food system consists of production, processing, transport and logistics, retail and consumption. It is however, a highly complex interconnected system where key issues include: the sustainability and stability of food production; resilience; economics; power relations of who influences the governance of food production, distribution and retail and how; inequalities of access; diet and how it relates to health; waste and environmental impacts of production. It is a system therefore with many complex inter-relationships and dependencies. In assessing the impacts of the COVID-19 pandemic and future risks to the UK's food and nutrition security, it is useful to expand on what the food system consists of and its complexity. The food system components include:

- Ecosystems: the wide range of natural processes that enable ecosystems to function and provide benefits (ecosystem services) via physical mediums (soils, water, biodiversity, ecosystems) that enable terrestrial and aquatic primary and secondary production of food.
- Up-stream supply chains and infrastructure to facilitate primary production (e.g. manufacturing of agriculture machinery; agri-chemicals; supplying services; research, training and extension, veterinary).
- Primary production: the cultivation and harvesting of food and the social and cultural diversity that interacts with the ecosystem services to produce food.
- Processing, logistics and transport and supply chains: processing and packaging; storage and distribution; wholesale and retailing (shops, markets, hospitality), advertising and marketing.
- Trade in commodities, including futures markets, and business finance and insurance.
- Food standards: what mechanisms are in place to ensure standards
- Consumption: The economics of access to food (affordability), purchasing behaviours and how individuals utilise food and are nourished.
- Food waste and packaging: how it is dealt with and downstream consequences.
- A key common factor in the food system is Human labour and skill, thus people are essential in respect of the ability of the food system to function, hence concerns due to disruptions to the ability of people to continue their roles within multiple sections of the food supply chain during

the pandemic and in the future due to climate change.

The complexity of the food system and diversity of sources may be considered as one aspect that gives it resilience. However, the drive for efficiency and concentration of production into a narrow range of commodities constrains this, implying increasing levels of vulnerability to a growing range and severity of threats.

Defining Food System Resilience

COVID-19, as a systemic shock that has critically impacted food systems, highlights the need to consider resilience as a guiding principle. Defining food system resilience is problematic as it depends on one's perspective.

Tendal et al (2015) provides the following definition of food system resilience: "*The capacity over time of a food system and its units at multiple levels, to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances... recognizing the importance of the time dimension in resilience*".

The pandemic is forcing a re-evaluation of what we mean by food system resilience and how it is achieved – 'resilience for whose benefit: the food industry or consumers (and within each of these groups)?' and 'what does resilience look like, and how do we achieve it?' The food system has evolved, certainly in developed nations, to one focused on economic efficiency rather than on resilience and sustainability, and does not consider externalities such as ecological or health costs. However, resilience comes at a cost because it is less efficient, whilst it also seeks to account for externalities.

Despite the fact the food system has continued to function during the pandemic, it is hard to argue that it is resilient when it contributes 34% to total global GHG emissions (Crippa 2021) and is the major cause of environmental degradation (IPBES 2019) and contributes to poor human diet. Resilience is therefore a function of sustainability and health as well as economic viability.

The 'just in time' value chain approach has greater exposure to threats, such as the pandemic, and can be seen as brittle in terms of resilience as it may be relatively easily disrupted or have supply chains broken (Parsons 2013; Benton 2019).

Diversity as a key component of stable systems. The Dasgupta Review states "Just as diversity within a portfolio of financial assets reduces risk and uncertainty, diversity within a portfolio of natural assets – biodiversity – directly and indirectly increases Nature's resilience to shocks, reducing risks to the services on which we rely (Dasgupta 2020). The same applies to the food system: resilience increases with greater diversity, yet we are increasingly seeing food production being homogenised into a narrow range of agricultural practices.

Further, to prevent increasing inequality, resilient food systems need to be develop in such ways as to not exacerbate existing social inequalities. Transformation of the food system may require additional social safety nets, as well as behavioural changes (e.g. reducing food waste, avoiding unnecessary purchases).

Different types of shocks

Not all shocks to the food system are the same: disruptions due to the pandemic have primarily been a demand side, yet climate change, biodiversity loss and ecosystem degradation are likely to produce, at least initially, supply side shocks. How impacts cascade through the food system and propagate insecurity will vary depending on the type and severity of shock, the connectivity and interdependence of supply chains and level of preparation and flexibility within.

There are different types of shocks:

- Demand side; as exemplified by the pandemic, demand side shocks arise from changes in economies impacting the affordability of food. The pandemic has had a split, with some experiencing increased hardship and reduced economic access, whilst other ("accidental savers") have experienced increased affordability of food.
- Supply side: reductions in the ability to produce food or transport it to markets and consumers.
- Shocks vary in their spatial extent: the pandemic has been global but with regionalised variations and scales of impact (I.e. contrast New Zealand with low numbers of people infected with the USA, Brazil and India with the highest).
    - Future climate shocks are likely to be regionalised rather than global, but may occur simultaneously (Bailey et al 2015)
- Shocks have different temporal scales: they can be either rapid- or slow onset. The pandemic was an immediate shock over a matter of months, prompting a rapid response of food supply chains tap into new sources of supply when previous sources became compromised. This response capability has highlighted the importance of an open and supportive trading environment.
    - Future extreme weather events are likely to be rapid but predictable, and geographically limited in extent.
- Duration: the pandemic (as of December 2021) has lasted 22 months and looking likely to continue for many more, possibly years. Similarly, long-term environmental degradation will result in long-duration shocks.
- Impacts from environmental degradation may be considered as more gradual in terms of shocks, such as desertification, though food producing ecosystems can rapidly decline and not recover (e.g. Canadian Atlantic Salmon stocks).
- There is variation within the supply chains: The COVID-19 pandemic affected all segments of the food supply chains, but not all sectors and products have been equally affected, with different products experiencing disruptions at different stages of the supple chain (OECD 2020).
- Biological shocks: animal diseases such as avian flu and foot and mouth, or plants pathogens can have an immediate impact but often are geographically limited in extent.
- Economic: these shocks can be both rapid, such as the 2008-9 financial crisis that saw large price increases and long-term repercussions, or slow such as recessions associated with fluctuations in demand.
- Trade policy shocks: In response to the 2008-9 financial crisis, some countries imposed export restrictions that served to exacerbate food shortages and price increases. As a result of these

impacts, global agreements have reduced the risks of export restrictions and there were few occurrences as a result of the pandemic. Trade wars can distort commodity flows: the US-China trade war resulted in agricultural exports of from the US falling from $15.8 billion in 2017 to 45.9 in 2018, resulting in the need for farm subsidies (PBS 2020).

Though there are different types of shock, there are compounding interconnections between them and increasing probabilities of simultaneous occurrences (Bailey et al 2015). Previous global scale shocks have been relatively short in duration, such as the 2008-9 financial crisis, but have had long-term repercussions but recovery has been possible. Future shocks from climate change and environmental degradation, however, may lead to long duration shocks from which only partial recovery is possible, for example if soil health declines past critical thresholds.

The food system pre- COVID-19

In understanding the consequences of the COVID-19 pandemic on the food system and hence food and nutrition security, and in the context of the overall project, it is important to recognise some key features, strengths and flaws of the system. The global food system had to evolve to post-second world war and rising population demands creating a productionist, industrial focus. This has come under criticism, with calls for re-aligning it to address current multiple issues (Poore and Nemecek, 2018, Willett and Rockstrom, 2019 Hawkes, 2020, Lang, 2020) including malnutrition, obesity, social inequality and the environmental damage the food system causes (c. 34% of global greenhouse gas emissions, biodiversity and habitat loss, soil degradation, depleted fish stocks etc. (Crippa et al 2021, Dasgupta, 2021, Benton et al., 2020). Whilst the measurable value of the global food system in 2019 was estimated to be c. $8 trillion, or 10% of the $80 trillion global economy, the economics of the food system does not include externalities such as the cost of health caused by poor diets (over- or under nutrition) or damage to the environment, estimated to be $6 trillion (World Bank, 2019).

The development of the food system has led to several key features:

- The post second world war policies and subsequent industrialisation of the food system focussed attention on production efficiencies rather than resilience and sustainability.
- Nearly 2 billion people are still considered to be food insecure whilst 820 million do not have enough to eat (FAO, 2020a).
- There are large inequalities in diet quality and food security, with both under- and malnourished people and others with high energy but low nutrition diets, both leading to different health problems.

"*Nearly every country in the world faces serious health problems linked to the consumption of either too little nutrient-rich food or too much energy-dense food*" (IFPRI 2015).

- Policies and economic drivers have led to the cheaper food paradigm, producing more food at lower costs, but without accounting for the costs of externalities.
- The concentration of food products is dependent on a small number of crops (wheat, rice, maize, soya).
- There is global scale exposure to price volatility due to national and regional scale risks (e.g. the 2008-9 food price spikes, extreme climate events).

- Agriculture accounts for a small percentage of the value of the food system. Only a small percentage of the cost of food to consumers can be accounted for by agriculture, the rest being spread across the supply chain (in the UK and US this is approximately 10 and 11% respectively) (World Bank, 2019).

However, global trade in food is an important stabilising aspect in international relations, creates employment and wealth. In respect of the evolution of the food system and hence the pre-COVID-19 state (and how the pandemic impacted it), the high value of the food system led to the development of a complex, skilled and in places technically advanced infrastructure (often with a high labour dependency) capable of moving large quantities of food quickly and cheaply over long distances. This can be seen as a strength in respect of the capacity to supply large numbers of people with food.

For the UK, this capacity (as well as many other economic, policy and cultural developments) has led to a heavy reliance on imports with almost half (45%) of what we consume coming from outside the UK (UK Gov. National Statistics 2020). The value of imports in 2018 was £46.8 billion, whilst exports were only £22.5 billion (Lang, 2020).

- This has resulted in an agricultural land use pattern and infrastructure that is not focussed on those food types that would mean greater self-reliance.
- Prior to the pandemic, around 8-10% of households in the UK were estimated to have been moderately or severely food insecure in recent years, whilst 1-2% had used food banks in 2018/19. For households with children, around 11% of children under 16 lived in food insecure households (approximately 1.4 million children) (Trussell Trust, 2019). A lack of official measurement means that the number of people affected by household food security in the UK is unknown (Tait, 2015). Estimates suggest that only around 1/3rd of food insecure households access emergency food aid via food banks (Douglas et al., 2015a) meaning that access to emergency food aid via food banks is a poor measure of the true extent of household food insecurity.

Background to inform impacts interpretation and future perspectives

Before presenting the project findings on pandemic impacts and future perspectives for UK food and nutrition security, it is worth highlighting the current food system situation and emerging environmental risks combined with potential changes in key drivers of global population and affluence. These set the context for what we need to change from and the likely demand-side pressures on the food system.

Scales of economic value

The food sector contributes approximately £111 billion a year to the UK economy and accounts for over 13% of national employment, being the UK's largest manufacturing sector. However, agriculture contributes c. £9 billion gross value to the UK economy (ONS 2021a), representing only 0.6 % of GDP. To put this into perspective, Scotch whisky exports accounted for c £5.5 billion gross value added to the UK economy.

A mismatch in production and dietary needs

What we produce as food does not align with what we should consume for a healthy diet. The food system has undergone considerable change in recent decades, with globalization and international food trade facilitating the consumption of new products, access to the same foods all year round rather than seasonal foods (Lang, 1999; The Guardian 2014), and cheap energy-dense, nutrient-poor foods. Consumption (particularly meat and dairy) has increased but so has the concentration of global energy intakes, through a few staple crops e.g. wheat, rice, soya, and maize (Antonelli et al., 2020). Figure 1 highlights the large mismatch between what is grown and what an optimal diet consists of, and what changes are needed in the UK diet to achieve multiple objectives. For example, a healthy diet should consist of about 50% fruit and vegetables, yet globally we only produce 17%, and in the UK the land area used for fruit and vegetable production is about the same as used by golf courses. The food system over produce cereals and starches, oils, fats and sugars compared to what is required for a healthy diet.

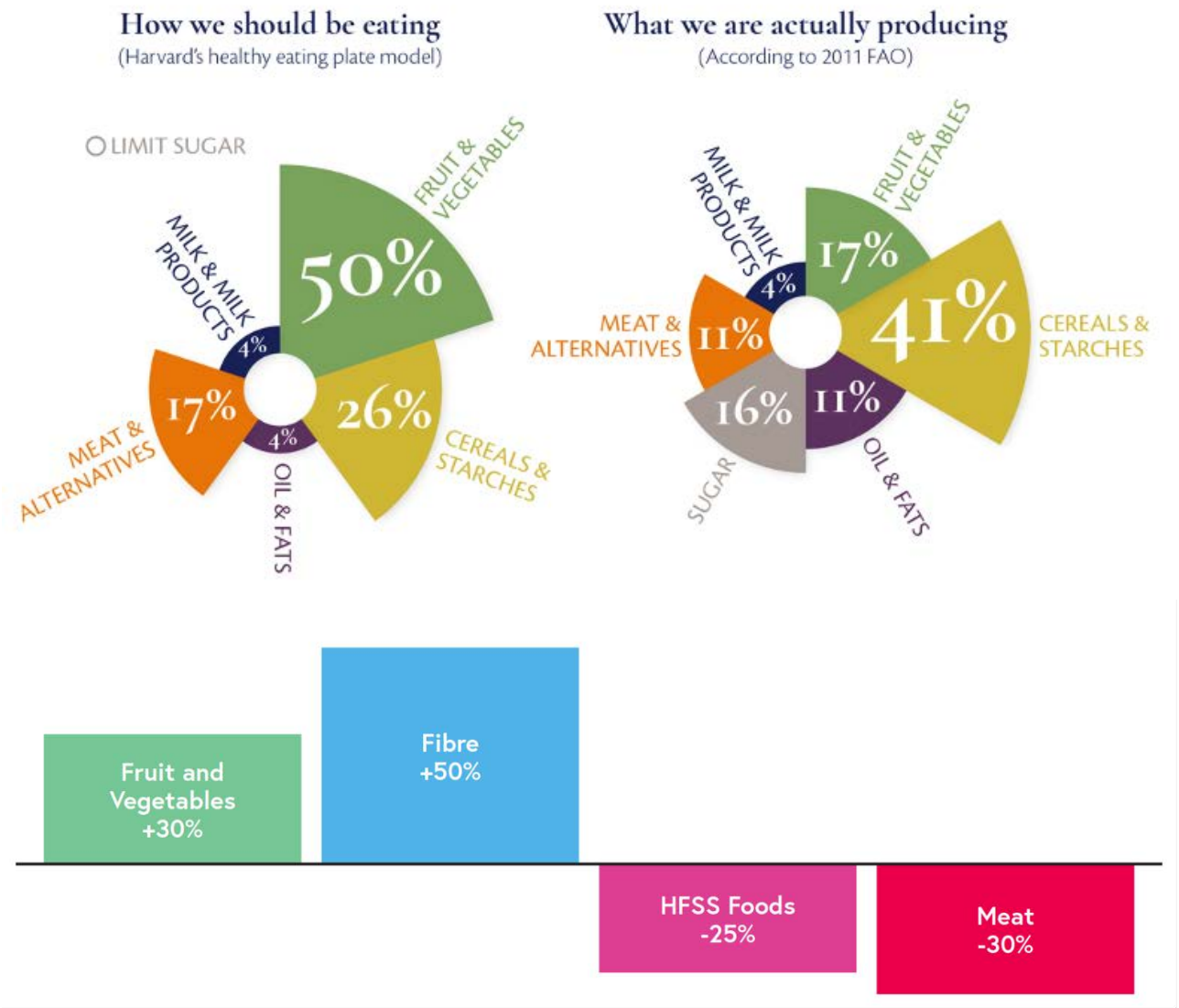

Figure 1. The difference between what food types are produced and what should be consumed for a healthy diet. Top: differences according to Harvard's healthy eating plate model, Bottom: Changes needed in the UK diet by 2023 (compared to 2019) to meet health, climate and environmental commitments (HFSS: high in fat sugar and salt). (Sources: Top - T Benton, redrawn from data in KB KC et al 2018, bottom, Dimbleby 2021)

Highly processed foods high in fats, sugars and salts have contributed to high levels of obesity, which incurs human health and productivity costs. Similarly, as highlighted below, the processes of food production cause environmental damage. The costs of these human health and environmental impacts are not included in the economics of food, but are instead treated as an externality. So, whilst the total agri-food sector in the UK may contribute approximately £120 billion to the UK economy, the total human health and environmental costs may be comparable.

A further consideration is the land area allocated to agricultural production (Figure 2) and how this interacts with rural communities and businesses, and also impacts the environment. These are

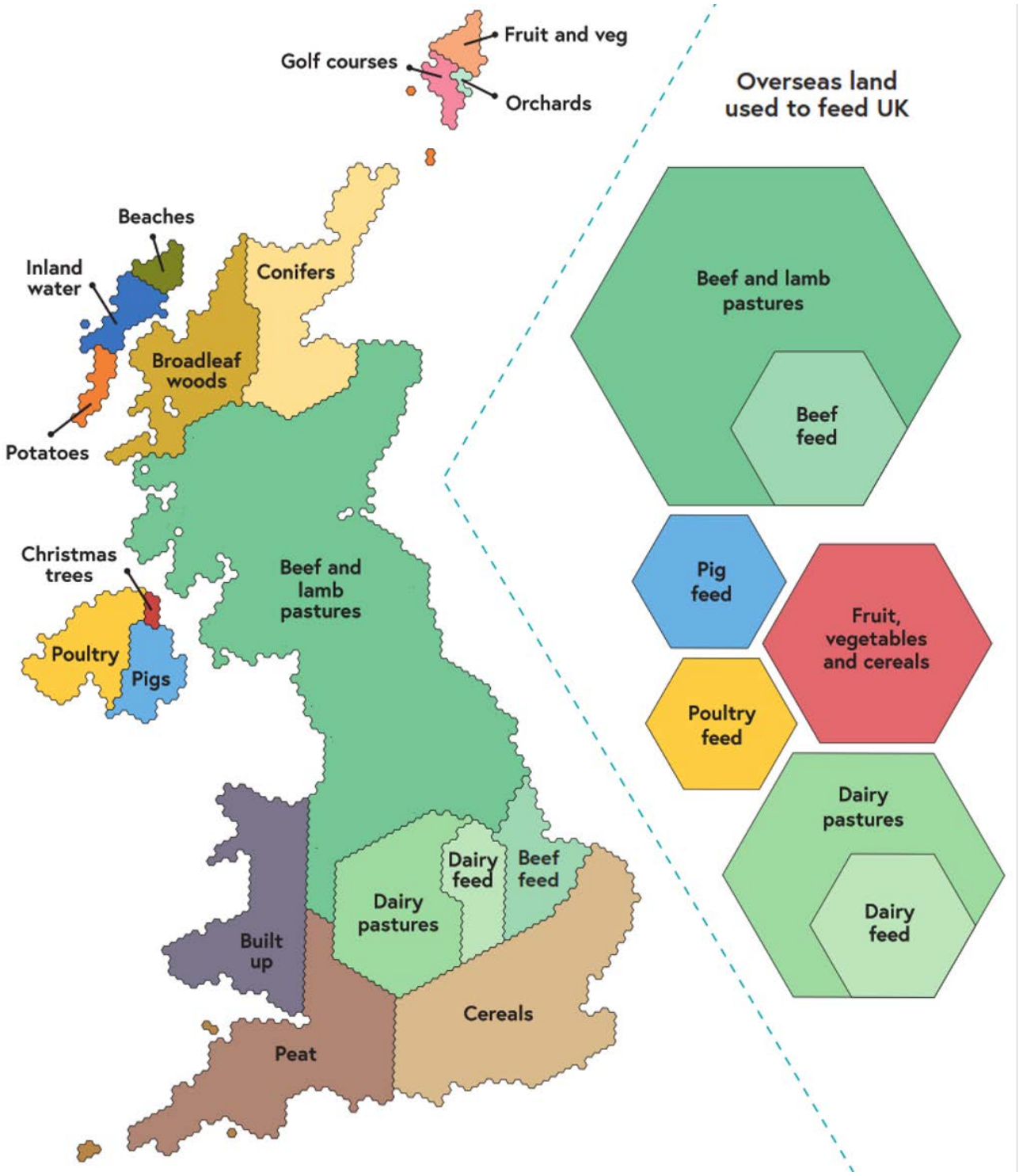

Figure 2. National land use areal representation and overseas land used to produce food for the UK. (source: Dimbleby 2021, p90)

key considerations when land use change is required to meet diet and environmental objectives – these are issues researched in sections 'UK food, diet and land options' and 'Land use and environmental health responses to changes in trade'. The project report Exploring the effects on UK food security and land use of four scenarios describing socio-economic responses to COVID-19 details analysis of the spatial context of changes in imports and exports and impacts on land use and environmental health under the four plausible scenarios (see project report Scenarios for UK Food and Nutrition Security in the wake of the COVID-19 Pandemic)

Emerging pressures and risks in context

A combination of growing population and affluence (Figure 3) will likely drive increased demand for food and hence additional pressures on the environment. Feeding 8 to 9 billion people in the next few decades without any further agricultural area expansion or over-exploitation of natural resources, whilst also achieving improvements in environmental health, will be a substantial challenge.

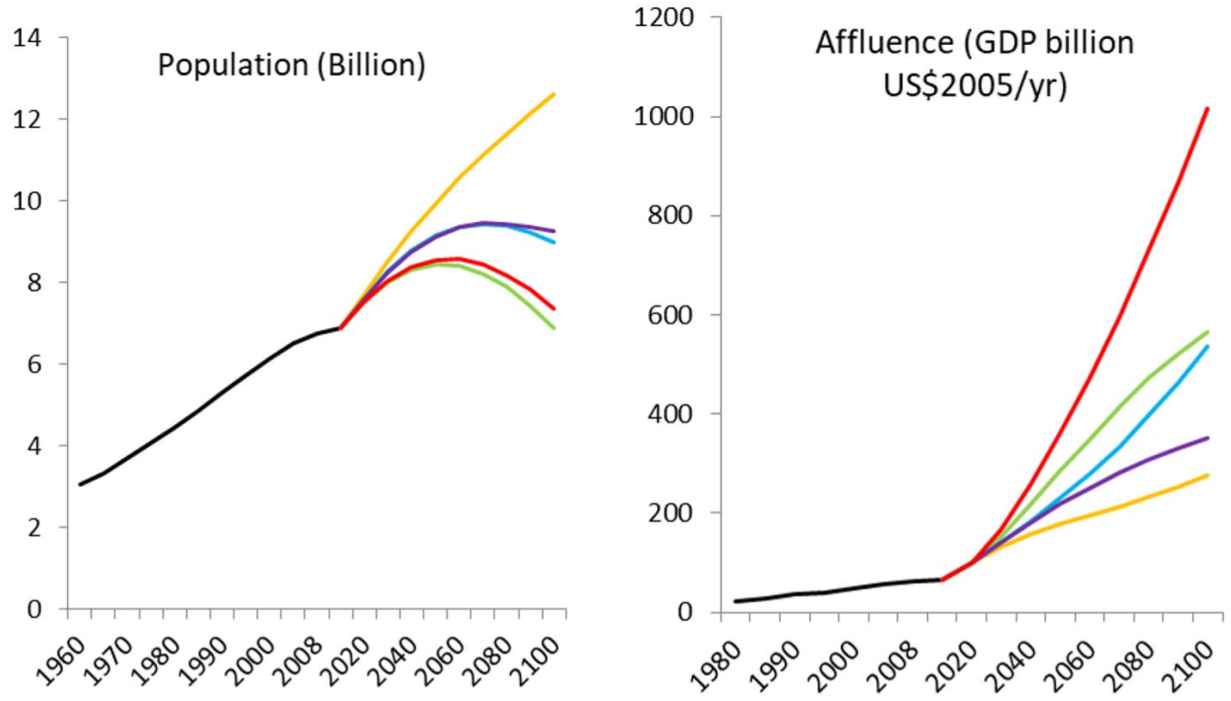

Figure 3. Population (Billion)(IIASA-WiC Pop) and B) Affluence (GDP billion US$2005/yr)(OECD) projections for five Shared Socio-economic Pathways (Moss et al 2010, Riahi et al 2017). Green = SSP1; Blue = SSP2; Yellow = SSP3; Purple = SSP4; Red = SSP5. Black = observed. Note: different historical period coverage for population. (Source: IIASA 2017).

There are large uncertainties in how population and affluence will develop in the future, but regardless of the different trajectories, the food system needs to be adaptable to cope with the range of possibilities.

Whilst an increase in affluence implies improved economic access to food, growing inequalities indicate a substantial part of the population will still experience insecurity. Moderate or severe food insecurity has been increasing gradually in the last six years, now affecting more than 30% of the world's population. It is estimated that the number of people in the world affected by hunger increased in 2020 during the COVID-19 pandemic, having remained virtually unchanged from 2014

to 2019.Between 720 and 811 million people in the world faced hunger in 2020, approximately 118 million more than in 2019 (the upper bound of the range could be as many as 161 million) (FAO 2021).

Risks in context: In respect of risks to global food production, it is worth noting that:

- Average global temperatures are set to rise by 2.1°C (range of 1.7 to 2.6°C) under the current Nationally Determined Contributions presented to the Glasgow CoP26 Climate Summit (Climate Action Tracker 2021). (see Figure 4).
- The food system accounts for up to 34% (Crippa et al 2021) of global greenhouse gas emissions (and therefore an area where changes are needed to reduce this amount.
- There is a rapidly reducing time-window within which the remaining permissible carbon emissions budget can be used and still keep the global temperature to 1.5°C (approximately 10 years). Figure 5 Illustrates that if emission reductions had started earlier, the rate of reduction would not have need needed to be so drastic as it is now.
    - The implication is that early action for preparation reduces the both the impact and long-term costs.
- There is increasing competition for land, for food, fuel and fibre production, and for land under protected status. Carbon offsetting schemes are increasing demand for tree planting on land previously used for food production.
- Soil erosion due to water is projected to increase, particularly in the Global South, by up to 66% compared to now (Borelli et al 2020). Wind erosion and other forms of impacts on soils will further decrease agricultural production potential.
- Agriculture is the largest cause of natural habitat loss and decline in biodiversity risking continued decline in the supply of ecosystem services (IPBES 2019).
- Approximately 70% of the worlds' available water is used for agriculture annually, including use of groundwater which is being depleted.
- According to recent global crop modelling research, climate change impacts on major breadbasket agricultural production are likely to occur earlier than previously thought, with indications that maize, rice and soybean yields will decrease due to warmer conditions, whilst wheat may increase in higher latitude areas (Jagermeyr et al 2021).
- The frequency with which extreme weather impacts food production globally is likely to increase, causing food price shocks (GFS 2015) and risking mass migration and civic stability (King et al 2015, Abel et al 2019).

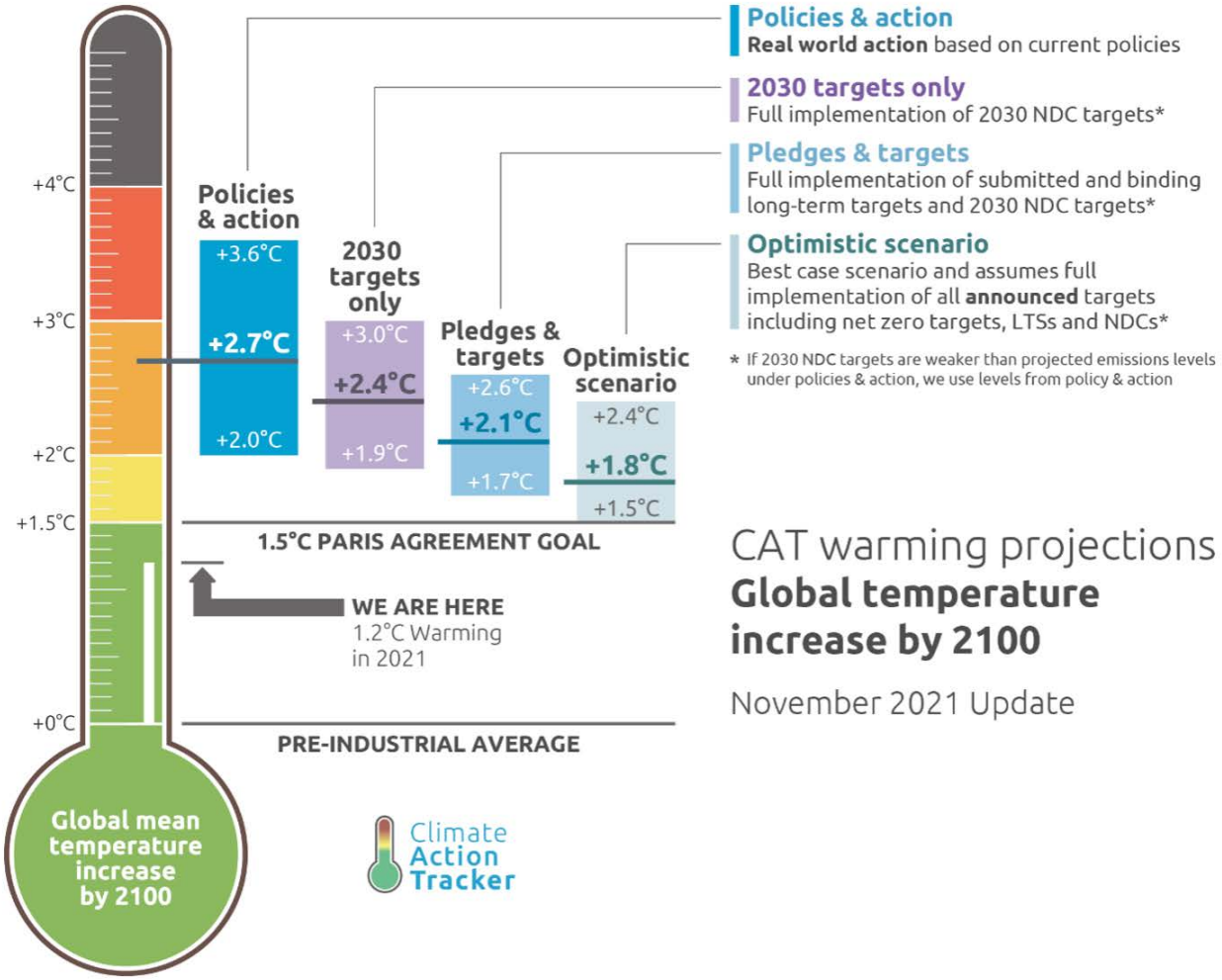

Figure 4. Potential global average temperature increases to 2100 based on a range of policy commitment scenarios (CAT November 2021).

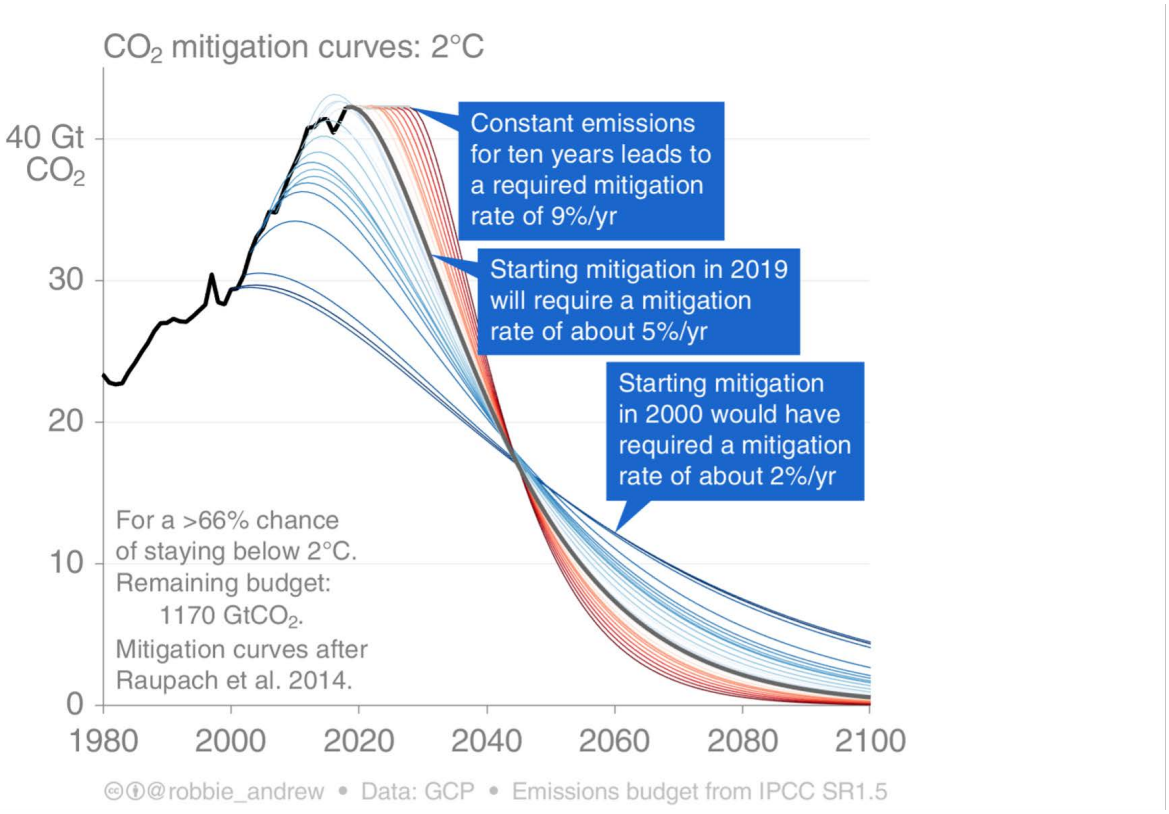

Figure 5. The accelerating need for change: Global carbon dioxide mitigation curves. (Source: Robbie Andrew, data from Raupach et al 2014).

Key Findings Part 1: Pandemic impacts

The following summarises the findings from four project reports published at varying times during the pandemic:

- UK food and nutrition security in a global COVID-19 context: an early stock take, Chatham House, ResourceTrade.Earth website. 6th November 2020.
- UK food and nutrition security in a global COVID-19 context: an update, Chatham House, ResourceTrade.Earth website. 8th March 2021
- Implications of COVID-19 for UK food supply resilience: Risks to food and nutrition security during and after the pandemic. Chatham House, 2nd December 2021.
- An overview assessment of the COVID-19 pandemic on the UK food and nutrition security, James Hutton Institute. 20th August 2021.

Impacts during the pandemic

- **Resilience:** The food system has been able to function during the pandemic shock in that it has maintained food availability and prices have remained relatively stable.
    - Overall, the pandemic has been a demand-side shock rather than a supply side one.
    - However, this raises important questions about how we define resilience of the food system: the ability to function during the pandemic does not imply long-term resilience to other pressures such as climate change or that the structure and products of the food system are well suited to healthy diets or sustainable production.
- **International trade:** the following are findings of a rapid risk assessment of the pandemic's impact on the UK's interactions with the global food system, conducted iteratively from mid-2020 to late-2021. Evidence from this period shows that:
    - The UK food system was already in a state of readjustment prior to the pandemic, due to Brexit; moreover, the ramifications of the UK's withdrawal from the EU are ongoing.
    - UK imports of food, drink, animal feed and agrochemical inputs have remained largely stable throughout the pandemic, although airfreighted fruit and vegetable imports contracted in March–May 2020, during the first national lockdown. In early 2021, food trade with Europe was acutely disrupted by the ending of the Brexit transition period.
        - In the first quarter of 2021 UK agri-food trade – both imports and exports – underwent significant contractions. Although the impacts of Brexit and the pandemic on the food system are in many instances closely interrelated, the ending of the UK-EU transition period at the end of 2020 appears to be the far more significant driver of these contractions.
    - UK food prices rose during the first national lockdown but fell for much of the rest of 2020. In 2021, however, UK prices have risen steadily, reflecting trends in global food prices, which have been increasing consistently since May 2020 despite generally plentiful food supplies.
        - International food commodity prices are now at their highest levels in a decade. This is largely due to longer-term supply and demand fundamentals, although there is also

some evidence of contributions from pandemic-related stimuli.

- Globally, while some regions have been affected by supply-chain constraints, and some markets by significant price rises, impacts have mostly resulted from recalibrations in demand. Nor have food- and agriculture-related trade measures implemented by individual countries been as severe or harmful as those adopted during the global food price crises of 2007–08 and 2010–12.
- Economic pressures resulting from the COVID-19 pandemic could yet cause major crises around the world, if people are unable to afford nutritious food. While supply impacts to date have been relatively mild, there is little evidence that this is due to widespread effective or coordinated interventions. Millions more people are now suffering from nutrition insecurity than at the onset of the pandemic.
- The global impacts of the pandemic are likely to affect the UK's food system for some years. With significant global vaccination inequalities, and with global food prices at their highest levels in a decade, the full extent of the impacts may not yet have been realized. Such pressures, coupled with continued Brexit-related impacts on the food system and uncertainties about the pace and shape of the UK's post-pandemic economic recovery, could yet cause shocks initially realized elsewhere to compromise UK supplies.
- As the UK deliberates on a National Food Strategy for England and begins to implement new agricultural initiatives and trade deals under a raft of post-Brexit legislation, it should champion national and global environmental standards to improve the long-term sustainability and resilience of the food system.
- On the multilateral stage, the UK has had significant leadership potential in 2021, including in its presidency of the G7 and as host of the 26th UN Climate Change Conference of the Parties (COP26). As it seeks to assert its post-Brexit 'Global Britain' narrative, the UK must position itself both internationally and domestically in the vanguard of supporting and enabling post-COVID food systems that forestall short-term food insecurity concerns and that promote long-term nutritional, livelihood, and environmental security.

- **UK Assessment:** In respect of the Food and Agriculture Organisation's four pillars of food security (availability, access, utilisation and stability), economic access due to reduced or lost income has been the key driver of increased food insecurity for some, exacerbating already large inequalities in society:
  - **Availability:** Food production levels, reserves and food system supply chain infrastructure have so far remained stable and able to meet demand. Most key food types have remained available.
    - A notable exception has been meat processing particularly poultry and pork where workplaces, especially large plants, proved to be unsafe because of high numbers of cases amongst workers. The emergence of processing facilities as 'hot spots' for disease transmission in multiple national contexts highlights a particular weakness in food systems where a few large plants process a high proportion of these meat types.
  - Access:
    - **Economic access:** People already on low incomes and those who have experienced loss of income have experienced severe economic and physical access difficulties. Hunger

and malnutrition are more strongly related to job loss and income reduction than with food supply chain disruptions.

- Food prices remained relatively stable after an initial increase on groceries inflation after March 2020. However, indications are that UK and global prices are increasing (December 2021).

- **Physical access:** difficulties due to the need for social distancing and movement restrictions meant the most vulnerable, particularly those with illnesses and disabilities have experienced greater difficulties in accessing nutritious foods.

  - **Utilization:** food purchase, preparation and consumption behaviours changed during the pandemic: evidence indicates both improvement in diet by those on stable, good incomes, but a deterioration amongst those on low income, particularly those already on poor quality diets.

  - **Stability:** The immediate prospects for continued stable availability are reasonable, but there are increasing risks from lack of economic access for low-income people.

    - The duration of a shock is a key aspect of the threat to stability: at the time of writing 20 months had elapsed since the start of the pandemic and availability of food has remained stable. Those who have had prolonged access difficulties have experienced due to low income have experienced increase insecurity.

    - Continued duration and the risk of additional shocks (i.e., due to climate impacts) will exacerbate an already stressed food system.

    - Primary production in 2020 in the UK experienced a substantial decrease in yield due to exception weather conditions (wettest February, sunniest May and dry spring, Storms Ciara, Dennis and Jorge resulting in flooding).

- Has the UK become food insecure due to the pandemic?

  - Our assessment is that as a whole the UK has not been food insecure during the pandemic, **however** insecurity has grown, with a substantial segment of the population has experienced food and nutrition insecurity, primarily through being on low income or losing / restricting economic access to food. Those with restricted mobility have experienced greater physical access difficulties.

- **Food insecurity has increased:** As of December 2021, The Food Foundation reports that 5.2 million adults (9.9% of all adults) have experienced food insecurity, whilst 2.5 million children live in households that have experienced food insecurity (Food Foundation 2021a).

  - The increase in children living in food insecure households has increased 27% above the pre-COVID period (2018).

- **Inequalities have increased:** The pandemic has exacerbated an already large inequality in food and nutrition security and diet quality within the UK (Food Foundation 2021b), risking the development of a two-tier cost and quality food system and further increasing inequalities.

  - There have also been inequalities in respect of the scale and type of impact on food businesses, with some retailers, on-line and takeaway businesses experiencing gains whilst others including rural and urban eat-in small businesses have suffered losses. This exacerbates market share inequalities and reduces business diversity.

- **UK food production was impacted:** Severe weather in 2020 resulted in substantial impacts on UK agricultural production. Primary production in 2020 was considerably lower than the average, for example wheat and oilseed rape yields may have been the lowest since 1981, down c. 38% production from 2019, despite increases in planted area.
    - There are concerns that policies relating to the removal of pesticides have exposed UK agriculture to increased pest and pathogen pressures.
    - Livestock: there were slight decreases in beef production, c. 8-9% decrease in sheep and lamb, but a c.9% increase in pig meat.
    - Against this, both pig meat and poultry processing was impacted due to the closure of large plants where Covid-19 cases amongst workers were exceptionally high. Due to the centralisation of this link in the supply chain and a just in time system, serious regional disruptions did occur, for example at the 2 Sisters plant in Llangefni, Wales (June, 2020).
- **Farm income fell:** In 2020 the main drivers for the fall in Total Income from Farming were a £999 million (-10.0%) fall in the value of crop output, **largely caused by unfavourable weather** and a £310 million (-20%) fall in the value of output from inseparable non-agricultural activities (diversified activities) due to Covid-19 lockdowns. These more than offset a £490 million (+3.4%) rise in the value of total livestock output. Overall input costs were almost unchanged (ONS 2021a).
- **Disruption** caused severe impacts on some food businesses and their processes, operations and financial viability, particularly the hospitality sector (which impact food acquisition and consumption behaviour) but not to the extent to risk severe national food and nutrition insecurity.
- **Supply chains:**
    - The transport and logistics sectors were able to adapt to enable continued functioning of the supply chains, despite severe labour and practice restrictions.
    - There was a generalised shortage of warehousing space due to an imbalance between outbound non-essential goods slowing or stopping, whilst inbound flows from imports to the UK continued. Lack of refrigeration capacity caused particular problems for some food types.
    - Significant changes in purchasing behaviour during Covid-19 compared with before included ways in which people obtained food, sources of buying food, frequency and types of food purchased.
    - Shortening supply chains connecting local producers to local consumers was facilitated by civil society activities, helping to alleviate some pressures on low-income consumers.
- **Risk Assessment – conclusions:** Food production globally in 2022 currently has a stable outlook (in the absence of any other type of shock), hence food availability may not be reduced. **However**, economic and physical access for an increasing number of people is likely to worsen leading to greater levels of food and nutrition insecurity and wider inequalities both in the UK and globally.
    - In developing response strategies to the pandemic impacts on the food system, governments and key food system actors need to avoid the risk of exacerbating the

problems associated with the cheap food paradigm (push for efficiency and cheap food without including health and environment externalities costs) in aiming to make food more affordable for people on low incomes, considering risks of pressures such as increasing energy prices.

- Under the definitions of food and nutrition security, the pandemic is a relatively short-duration shock (as opposed to long-term threats such as climate change) hence the response to COVID-19 is an indicator of short-term food system resilience. **However**, this does not imply that the food system is resilient and sustainable to other types of shock (i.e. climate extremes) or long-term deterioration (i.e. ecosystem degradation). The food system (in the UK) has adapted and coped to enable food and nutrition availability to many people, but this should not be seen as a sign of overall food and nutrition security resilience.

International trade perspective

The following summarises three reports looking at international trade produced during the project, please refer to these for full details:

1. UK food and nutrition security in a global COVID-19 context: an early stock take
2. UK food and nutrition security in a global COVID-19 context: an update
3. Implications of COVID-19 for UK food supply resilience: Risks to food and nutrition security during and after the pandemic. Chatham House, 2nd December 2021.

In Summary:

- Prior to the pandemic, the UK food system was in a state of readjustment due to Brexit. Since January 2021 the food system has had to adjust to new trade conditions.
- Initially UK imports of food, drink, animal feed and agrochemical inputs largely remained stable throughout the pandemic though airfreighted fruit and vegetable imports experienced greater disruptions in the first lockdown, but less so in subsequent ones. Overall international supply remained robust.
  - In the last quarter of 2020 the value and volumes of food, feed and drink imported to the UK followed similar patterns to the previous two years, despite the acute stresses caused by short-term border closures just prior to Christmas.
- Global food prices remained relatively stable during the first few months of the pandemic (see below) compared to previous price shocks in 2008 and 2010, but as of early 2021, global food prices had been experiencing the sharpest and most sustained increases since the 2010-11 food price crisis and by January 2021 had reached the highest monthly average value since mid-2014 – up 11 per cent from a year earlier. Although pandemic-related factors are at play, they do not appear to be the primary drivers of food price rises. Although the value of £ Sterling relative to the Euro declined by 10% from February 2020 to March 2020, subsequently the value of £ Sterling to the Euro remained relatively stable during the rest of the pandemic in 2020 as both the UK and EU faced similar challenges.
  - These prise rises and other concerns about different vaccination rates, uneven economic recoveries and Brexit trade readjustments, plus risks of other forms of shocks (e.g. climate

impacts) indicates that food and nutrition security in the UK, and globally, may remain at risk.

  - If the COVID-19 responses in the UK and Europe diverge, this may affect exchange rates and thereby the profitability of UK farm production. Strengthening £ Sterling to the Euro in Spring 2021 may dampen UK farm prices.

- UK food exports remained relative unaffected in terms of both value and volume in the last quarter of 2020. New trade and customs arrangements at the end of the Brexit transition period caused complications and delays to supply chains, and impacted fresh foods (horticultural and fish particularly), especially for Northern Ireland.
- Agricultural input prices remained largely stable during 2020, suggesting few supply constraints.
- Farmgate prices rose for arable goods but contracted initially for meat suggesting suppressed demand and market uncertainty, but with a subsequent increase. Consumer price data suggests food price inflation from April to May 2020 following the first lockdown and deflation thereafter until the end of the year, with the trend reversing in January 2021.
- Globally, the pandemic has affected countries in different ways in terms of COVID-19 cases and responses and how these have impacted production, exports / imports and exchange rates. While there were some concerning supply-chain constraints in some countries, and some significant price rises in some markets, generally food supply remained plentiful and impacts have mostly been the result of demand contractions.
- Some countries have implemented food and agriculture trade measures, generally to restrict exports and liberalize imports, but these have been nothing like as severe or harmful as the unilateral measures adopted during the 2007-08 and 2010-12 food price crises.
- Economic pressures resulting from COVID-19 could yet cause major crises around the world if people are unable to afford nutritious food. While impacts to date have been relatively mild, there is little evidence that this is the result of effective or coordinated interventions.
- The global impacts of the pandemic, particularly the economic effects, will likely affect the food and nutrition security of segments of the UK population, particularly those on low income for some years. It is likely that the full scale of the impacts is yet to be fully realized.

Since the initial report was published in November 2020, in general, fewer supply-side disruptions were observed in the second wave of the pandemic because governments have been able to more effectively respond than they did in the spring of 2020 (Giertz, 2020).

Global Food Prices:

The FAO Food Price Index (FPI) has remained stable since 2015, but declined in the early stages of the pandemic (February- May 2020) but subsequently increased from June 2020, along with all commodity types now on an upward trend (except meat) (Figure 6). As of January 2021, the FPI reached a six-year high and was 11% higher than at the same time in 2020. However, the change in FPI during the pandemic is less than that which occurred following the 2008-9 financial crisis.

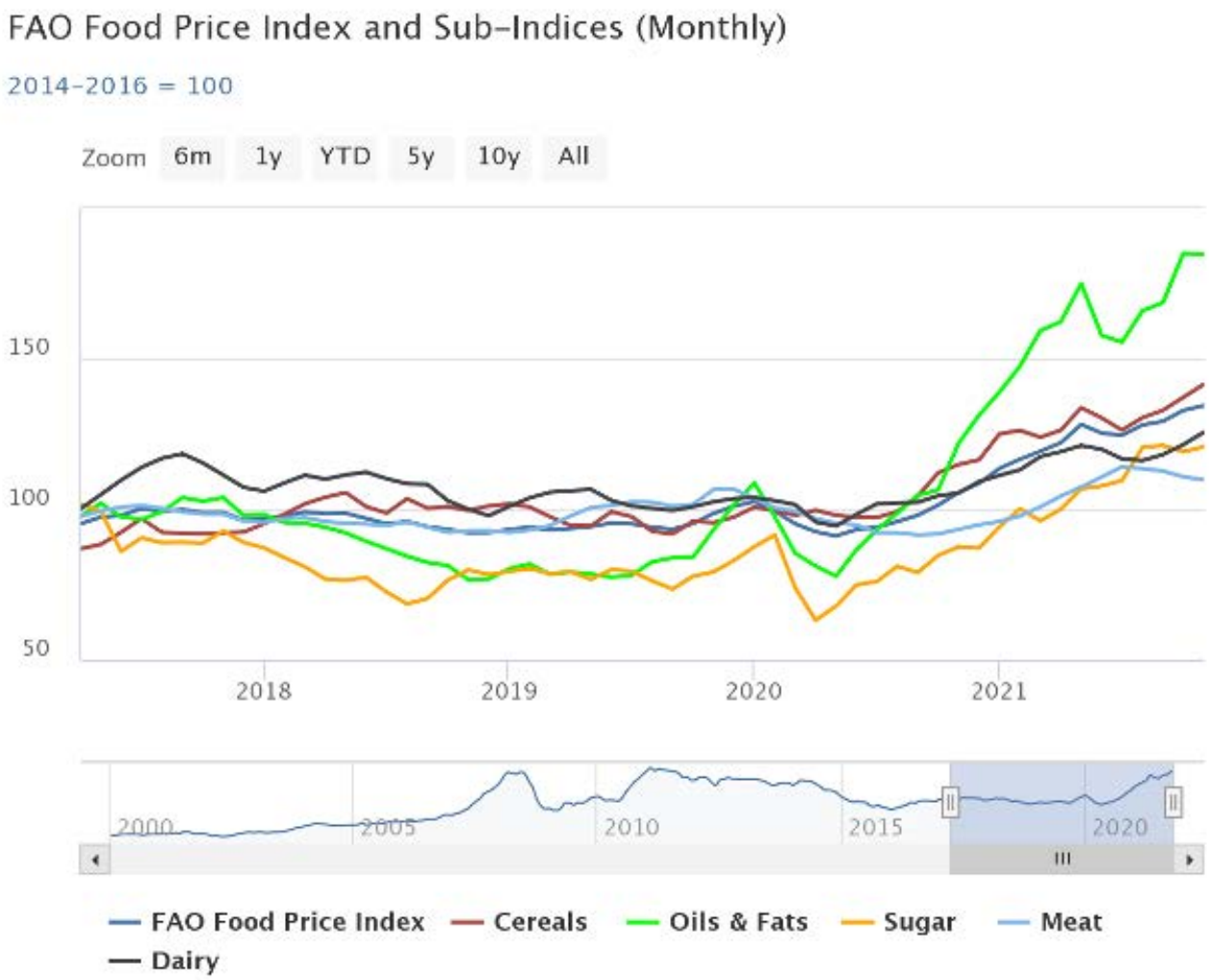

Figure 6. Monthly Food and Agriculture Organisation (FAO) Food Price Index and Sub-Indices from July 2017 to November 2021. Note: Index is 2002-2004 = 100 (Source: AMIS - http://www.amis-outlook.org/indicators/prices/en/)

Pandemic impacts: UK Assessment

The following summarises the project report An overview assessment of the COVID-19 pandemic on the UK food and nutrition security, please refer to this report for full details.

Food System Sector Summary

The overall food system has adapted and coped with the pandemic shock, though there are many exception examples where businesses, particular food types and parts of the food system have been severely impacted.

- **Producers:**
  - Overall supply (UK and international) has managed to meet demand.
  - Labour shortages impacted production and ability of businesses to function whilst labour costs increased.
  - Changes in demand (closure of hospitality, type of produce consumed) required

readjustment of business models, to which the sector was adaptable.

- **Processors:**
  - Food processing industry has managed to meet changing demands by accessing new markets (e.g., online) and creating new strategies (e.g., adapting packaging to retail)
  - The sector was severely impacted by COVD-19 outbreaks, directly in the case of some major pig meat and poultry processing plants, which incurred considerable costs and changes to procedures.
  - Labour shortages were reported and a disproportionate number of low-income employees exposed to risks.
- **Retailers:**
  - Consumer behaviour led to increased sales of food and some retailer revenues.
  - Initial reductions in discounts by supermarkets led to price inflation.
  - Hospitality restrictions have threatened many businesses and changed current consumer behaviour.
  - Original advanced preparation by retailers for potential shortages due to Brexit helped reduce pandemic impacts.
- **Logistics and transport:**
  - Movement and storage of goods was severely impacted due to disruptions because of labour and warehousing shortages and cross-border restrictions.
  - Airfreight decreased initially but increased due to restrictions on shipping, road and rail.
  - Despite severe impacts, the logistics and transport infrastructure has helped to maintain food availability.
- **Upstream supply chains (production facilitation):**
  - The provision of supplies and services (fertilisers, veterinary etc.) to enable primary food production was able to continue with limited impact on primary production.
  - Changes in public consumer food demand and behaviour had little immediate impact on the pre-production up-stream sector.
  - On-farm practices often use lone-working approaches so less impacted by social distancing restrictions.
- **Research and academic perspective:**
  - Highlighted the vulnerabilities of the ‘just in time’, economic efficiency driven food system.
  - The pandemic has confirmed the already identified flaws in the food system in respect of inequalities and lack of inclusion of externality costs (health and environment).
  - Whilst the food system may have adapted and coped with the pandemic shock (in the UK), this shouldn’t be seen as a sign of system resilience.
- **Policy and food system governance:**
  - Job retention (c. 9.9 million) and other employment protection schemes favoured those

already in employment but limited the number of people exposed to loss of income, hence reducing exposure to food and nutrition insecurity. However, many self-employed or on zero-hour contracts were ineligible for support and many of those reliant on social provision have found support to be insufficient.

  - The need for lock down policies has resulted in various business sectors shutting down or closing and hence large numbers of people losing income so exposing them to food insecurity. The Food Foundation's most recent reports show that the percentage of food insecure adults was 7.6% pre-COVID, rising to 9.7% at the start of the pandemic, increasing further 9.9% in the period February to July 2021, affecting 5.2 million adults.
  - Measures focussed on the food system have generally enabled it to function, including recognising people producing and distributing food as key workers.

- **Third sector:**
  - Civil society has been crucial in helping to alleviate pandemic impacts on food and nutrition security, at a time when there was already a substantial reliance on third sector support, through food banks, dissemination of information, coordination of efforts and support to industry.
  - Charities and NGO's have had to adapt rapidly to cope with the impacts but have often experienced great difficulties in the ability to operate and secure funding support.
  - The pandemic has highlighted weaknesses in the food system, particularly in relation to the number of people vulnerable to food insecurity, that the third sector had already made clear.
- **Food System Finance:**
  - Compared to other areas of the economy, overall the food sector has been less impacted financially (with the exception of hospitality businesses) due to continued demand and ability of the production, logistics and transport, processing and retail sectors to operate.
  - A high percentage of self-employed within the agriculture, forestry and fishing sector (AFFS) meant c. £80 million claim value in the UK under the Self Employment Income Support Scheme. The number of people furloughed in the AFFS was similar to the whole UK economy.

The hospitality sector has been hit particularly hard due to lock down conditions, but with variations within it (ONS 2021b):

- The impact has been uneven; bars and clubs have fared the worst, but campsites had a relatively better year than the rest of the sector.
- Consumer spending on hospitality started to increase in May 2021 but remained at less than 70% of pre-pandemic levels; a similar picture is seen in turnover - in May this remained one-quarter lower than 2019 levels.
- Spending by businesses in the hospitality sector has seen smaller increases compared with consumer spending in May 2021; payments to suppliers from food and drink businesses have remained around half of pre-pandemic levels.
- Confidence of business survival in the hospitality sector started to increase in May 2021 but remains below the all-sector level.

- Job vacancies in the hospitality sector have seen large increases and are higher than pre-pandemic levels; however, in June 2021, the number of employees within the sector remained 11% below February 2020 levels.

The restrictions on hospitality meant a large shift to more home consumption and less consumption away from home, with substantial impacts on supply chains that needed required rapid realignment to meet the change in demand source.

Agricultural and fisheries production

Primary production in 2020 was lower than average, wheat yields were the lowest since 1981. Winter wheat and barley yields were down 18%, spring barley and oilseed rape down 6% and 15% respectively. The decrease in production was in part due to variable weather conditions, ranging from the wettest February on record (UKMO, 2020a) (restricting field access for pre-sowing preparation and sowing) to an exceptionally dry spring with May being the sunniest on record (UKMO, 2020). There are also concerns that policies relating to the removal of pesticides have exposed UK agriculture to increased pest and pathogen pressures. Hence despite large increases in planted areas for some crops, e.g. spring barley up 54%, there was little net gain on 2019 yields. The total utilised agricultural area (UAA) in the UK decreased slightly in 2020, to just under 17.5 million hectares. The area of total crops and permanent grassland also saw decreases, whereas uncropped arable land had a 57% increase. The total area of horticultural crops increased by 3.7% to 169 thousand hectares. Vegetables and salad for human consumption make up the majority (72%) of this area and increased by 6.2% to 122 thousand hectares in 2020.

There were slight decreases in livestock numbers and slaughterings (compared to February 2020) leading to reduced production of beef (1.6%) and mutton and lamb (9.3%), whereas pork increased by 9.5%. The price of animal feed remained relatively stable even after the start of the pandemic. Since August 2020 there was an increase across all feed types. Meat products and dairy retail was impacted by closure of the hospitality sector and time delays in transferring to other supply chains.

One of the biggest threats to production came from skilled labour shortages, due to closed borders and travel restrictions for temporary workers. The long-term neglect of the agricultural skills market is clear and the lack of investment in skills and training of farmed staff was exacerbated by COVID-19, with arable and mixed farms often unable to source skilled and experienced workers. Low wages remain a substantial issue in attracting people to work in the agricultural sector, despite employment demand following the loss of EU migrant workers.

The quantity of fish landed in 2020 by UK vessels was only 2% less than in 2019, however the cumulative value of the catch was down 21%. Contractions on international trade, notably exports, heavily affected the seafood industry (Seafish, 2020a, b) in the UK, resulting in a severe loss of income.

Food prices and consumer behaviour

In the first month of the initial March 2020 lockdown there was a 2.5% groceries inflation increase, which declined to 0.5% above the January start of year value by August 2020. This increase was seen more so in the larger supermarkets than discount shops. There was gradual deflation in the summer of 2020, partly due to promotions returning to normal levels. The number of unique

products purchased decreased by 8% in the first week of the lockdown, with this reduction in product variety persisting through to August. The inflationary spike seen at the beginning of the first lockdown was experienced by households across the income distribution, but was larger for better-off households, though proportional to income less impactful. However, the reductions in available promotions at the start of the initial lockdown impacted those low-income people who would normally rely on discounted products. However, the gap in inflation experience across different income levels has since closed. Food items assessed within the Consumer Price Index (CPI), since February 2020 indicate there was little overall change up until December 2020. The prices of imported food products remained stable, though this evidence does not incorporate indications of quantity or quality.

There was a 70% increase in online grocery shopping by August 2020 compared with 2019 (Jaravel and O'Connell, 2020a, b). Significantly more people grew their own food during Covid-19 compared with before Covid-19 (EU Food-COVID Network 2021). Across all food categories (fresh fruit and vegetables, other fresh food such as meat, fish and dairy, and non-fresh food) people purchased more food online and/or from local producers, while less people purchased food at supermarkets or discount stores.

Food Availability and Access

Despite the global nature of the impacts of the pandemic causing considerable disruption, some limitations on cross-border trade (due to physical virus controls and export restrictions), individual cases of impacts on particular food type availability (i.e. flour was available but demand after the first lockdown presented packaging problems) and poor harvest yields in the UK, overall food availability did not decrease to levels that threatened food insecurity in the UK from the food access perspective. Primary agricultural production was able to maintain supply sufficiently well enough to enable global trade to continue and meet demand. Food production within the EU, as the UK's primary source of imports, remained stable. Decreases in agricultural output and reduction in farm income were observed but the scale of these is comparable with previous years (excluding considerations of the climatic impacts on UK primary production), indicating the reasonable potential for agricultural sector recovery.

Economic access is the clearest cause of food and nutrition insecurity in the UK, given that supply and prices generally remained stable in 2020 and the infrastructure enabling the food system to function has remained operational. Large sections of society experienced increased economic access difficulties in accessing sufficient nutritious food for their needs due to a combination of loss of income, delivery of work-age benefits, benefit caps, rising debt, poor or insecure employment and health problems, and the disruption to school meal provision due to school closures (Trussell Trust, 2020). The Impacts of the pandemic on food security through economic access are multi-layered and complex, often existing alongside other challenges (including debt, job insecurity or loss of employment, health and mental health, care responsibilities etc.):

- Loss of income exacerbated existing food insecurity and other vulnerabilities. The poorest households spent a higher proportion of income on food and so were more vulnerable to income shocks and food insecurity.
    - Pre-existing food insecurity increased for those on low income, income support, zero-hour contracts or without reliable salaries / self-employed, people with existing physical or

mental health problems.

  - Social food sharing opportunities (e.g. through family meals) were reduced.
  - Those working in sectors that were unable to work remotely and / or had caring responsibilities, particularly women.
- Whilst furlough and income support (Universal Credit, mortgage / debt holidays etc.) helped many people, large gaps remained in people's ability to access safety nets.
  - There remains a stigma about using food banks.
- Changed physical access restricted opportunities to acquire food from lower cost outlets.
- Changes in diets to reduce costs: vulnerable people reverted to low-quality and less varied diets. This exacerbates malnutrition, stress and anxiety.
  - People compromised on food safety, by stretching 'use by' data advice.
- Costs of home delivery fee (which becomes a large proportion of the weekly overall food budget) or lack available delivery slots from providers.
- Low-income people may have taken on more debt to survive, reducing their ability to break the poverty trap.

Food Utilization

The pandemic had a fundamental impact on food utilisation, with lock down rules creating new social dynamics and household organisation. Eating out reduced considerably and the number of meals at home tripled in some cases. The pandemic initially led to fundamental changes in purchase, consumption and food waste behaviors (Roe et al 2020). More people prepared and ate food in the home but eating, physical activity and other weight-related lifestyle behaviours were impacted, with people experiencing weight management problems (lack of motivation and reduced self-control), increased consumption of snacks and alcohol. People with obesity may have been disproportionately affected.

Food Stability

Food stability integrates the other three pillars of food and nutrition security (availability, access and utilisation) to consider the ability to obtain food over time. The FAO states "*Even if a persons' food intake is adequate today, they are still considered to be food insecure if they have inadequate access to food on a periodic basis, risking a deterioration of their nutritional status. Adverse weather conditions, political instability, or economic factors (unemployment, rising food prices) may have an impact on a persons' food security status*" (adapted from FAO 2008). Under these definitions, our assessment is that the UK has not experienced chronic insecurity thus far in the pandemic. Prior to the pandemic, there were already a substantial number of people experiencing either chronic or transitory food insecurity in the UK. The difficulties arising from worsened economic access has meant significantly more people have experienced transitory insecurity. Quantifying these numbers is problematic but it is clear that those who were already vulnerable to income loss have been those directly impacted.

However, the extent to which the UK has avoided more widespread issues of transitory insecurity remains to be seen as the global impacts of the pandemic on availability and access, and subsequent utilisation, are still unfolding alongside other issues, i.e. Brexit and trade deals.

Gender and inequalities

The pandemic has affected male and females differently: hunger and food bank use affect women disproportionately, as they tend to be the 'shock absorbers' of poverty among children: One study found they were twice as likely as men to be food insecure because they were more likely to skip meals so their children could eat (Ruxton and Burrell, 2020). Also, violence against women has increased for several reasons including job losses by men and the 'stay at home' guidance and closure of hospitality.

The work done by women and minority groups in food systems also puts them at a higher risk of exposure to COVID-19 (Forsythe et al., 2020). In the UK, women make up 55% of the food and accommodation sector. People from Black and Minority Ethnic and LGBTQ+ groups in the UK are also over-represented in public-facing roles in the food sector (e.g., in restaurants and supermarkets) (BBC 2020).

Waste

There have been large differences between households in terms of changes in amount and type of food waste, but amongst self-reported food waste, it had stabilised at levels estimated for June 2020, which were well below pre-lockdown levels. Food waste increased amongst those households with people returning to work or school, and where time pressures had returned after the first lockdown. Food management behaviours during lockdown, such as checking date labels and guidance, using or freezing left-overs, checking fridges for stock etc. have endured (Wrap, 2020). 70% of food waste comes from households (post-farm gate), which is associated with more than 20 million tonnes of GHG emissions yearly and valued at £14 billion a year.

Lessons learned from the pandemic

To help better understand how we may earn from the pandemic to prepare for future climate change and environmental degradation impacts on the food system, it is useful to identify similarities and differences between the two types of disruption.

- **Prevention is better than cure:** The costs of the pandemic now far outweigh what it would have cost to take preventative measures to reduce the risks of a virus developing and spreading. The Global Preparedness Monitoring Board estimates the pandemic response costs so far to be $11 trillion, with a future loss of $10 trillion in earnings, whereas preparing for a pandemic would have cost the world $5 per person. In 2006 the Stern Review (Stern 2006) for example argued for 1% of GDP to be invested in climate change mitigation (revised to 2% in 2008). Whilst the review may have had it's limitation. The underlying message of early investment to reduce overall costs holds true. Figure 5 highlights what would have been the benefits of earlier greenhouse gas emissions reductions.
- **Food production:** the pandemic caused some disruption to food production globally, primarily due to labour availability issues, but yields were generally higher than average. The UK however

in 2020 experienced a decrease in production of cereals due to weather extremes. Future climate events are likely to cause production shocks through increasingly variable climatic conditions and extreme weather events which may be experienced earlier than previously thought i.e., corn and rice yield decreases by 2030 (Jagermeyr et al 2021).

- **Timescales:** The pandemic was a new instant shock unfolding very rapidly in a matter of months and may last for several years to come, whereas environmental change has been occurring gradually but likely to accelerate and continue without immediate mitigation. Impacts are likely to be frequent but sporadic in nature.
- **Spatial scales:** the pandemic has had a global impact on the food system but with regional variations. Environmental change is also likely to have spatial differences, the consequences of which will depend on severity of impacts and risks of these occurring simultaneously in different locations (GFS 2015).
- **Differentiated societal impacts:** The pandemic has had an instant impact on everyone globally, whereas future consequences of climate and environmental change on food and nutrition security will likely be spatially and temporally dispersed. Both the pandemic and environmental change are currently impacting the most vulnerable sections of society. Environmental impacts are likely to be longer-lived. However, the pandemic has, and environmental change will impact differently on sections of society, with those already experiencing food and nutrition insecurity continuing to be those most vulnerable. Climate change and environmental degradation are likely to increase social inequality divides.
- **Food prices:** During the first year of the pandemic prices remained relatively stable but started to increase later in 2021, but not due to shortages of produce. Climate and environmental change are likely to result in increased sporadic food shortages, set against the context of an increasing global population with growing affluence leading to increased demand.
- **Food processing:** Particular components of food processing, especially meat and poultry processing industries, came under severe pressure as many large, centralised facilities across the globe saw excess transmissions of COVID-19 and were subject to strict public health measures including temporary closures. The 'just in time' supply chains in these processing sectors exacerbated effects through knock-on effects to suppliers and producers whose perishable goods went to waste. Such effects will not occur in the same way from future climate change although shock events affecting critical links in the supply chain, for example extreme weather affecting ports, are now highlighted as vulnerabilities in the food system.
- **Social confusion and need for clear information:** the pandemic and climate change (and other environmental risks) share a common feature of both having unclear messages provided by multiple sources leading to social confusion. The pandemic has demonstrated the damage misleading and politicised information can cause, and there has been a long history of dis-information and politicisation of climate change causing polarisation and uncertainty, reducing the ability of society to respond at pace and scale. In the face of emerging risks there is a need for clear messages from trusted communities. Whilst there has been some clear messaging on COVID-19, i.e. washing hands etc, there remains a substantial gap in messages on climate change and how individuals can reduce their impacts.
- **The lived experience:** the pandemic has impacted everyone, albeit differently, with those on higher and secure incomes being more protected than those on low and insecure incomes. Conversely, whilst some, particularly the poorest in the world are already experiencing the

impacts of climate change and environmental degradation, most people in developed countries (with the exception of those who have experienced the impacts of some extreme weather events) have not encountered impacts yet.

- **Trust in science:** The pandemic has tested the relationships between society and science, and policy makers with scientists. A sufficient majority of society and policy makers have trusted science to enable scientists to inform immediate policy making decisions and actions on preventative infection spread responses and the development and roll out vaccination programmes. As with pandemic risks, scientist have long warned about the dangers of climate change and environmental degradation (i.e. IPCC 1990, Kendall 1992, Ripple et al 2017), but there is an important distinction in perception: the pandemic has been immediate and tangible, whereas climate change has until recently been seen to be a problem of the future.

Informative perspectives and conclusions on the lessons learned from the pandemic for sustainable food systems can be found in Bisoffi et al (2021).

Text Box 1: Other UKRI COVID-19 Food Security Projects

The UKRI has funded several projects assessing COVID-19 and the food system. These cover a range of aspects of the food system and scales of focus. In the interests of increasing the value of the UKRI Agile Response COVID-19 focussed research, the details of the projects are provided here.

Food system impacts of COVID-19. Centre for Rural Policy Research, University of Exeter.

About the project | Food system impacts of COVID-19 (exeter.ac.uk)

Note: The University of Exeter team has been commissioned to provide an overview of the UKRI Agile Response projects looking at food, some of which are detailed below. At the time of writing this has not yet been published, but we recommend visiting their project website to access it when available or contacting the UKRI.

The local as a site of food security resilience in the times of pandemic. Institute for Sustainable Foo, University of Sheffield. The local as a site of food security resilience in the times of pandemic | Institute for Sustainable Food | The University of Sheffield

Resilience of the UK seafood system to COVID-19 disruption (RiseUp), Scottish Association for Marine Science. RiseUp — The Scottish Association for Marine Science, Oban UK (sams.ac.uk)

Feeding the nation: seasonal migrant workers and food security during covid-19 pandemic, University of Leeds. https://feedingthenation.leeds.ac.uk/

The impact of the covid-19 crisis on nutrition. Institute for Fiscal Studies. Research - Institute For Fiscal Studies - IFS

Meeting food vulnerability needs during covid-19: applying a systems approach to evidence based policy and practice. University of Sheffield. http://speri.dept.shef.ac.uk/food-vulnerability-during-covid-19/

The impact of the covid-19 crisis on food security. Institute for Fiscal Studies. Research - Institute For Fiscal Studies - IFS

Local food-growing initiatives respond to the covid-19 crisis: enhancing well-being, building community for better futures. Open University. https://cobracollective.org/news/digitalstories/

Capitalising on covid-19 as a trigger for positive change in food waste behaviour. University of Leeds. https://business.leeds.ac.uk/dir-record/research-projects/1782/capitalising-on-covid-19-as-a-trigger-for-positive-change-in-food-waste-behaviour

Food in lockdown and beyond. City University of London (NHIR funded). https://blogs.city.ac.uk/covid19foodstudy/

The impact of covid-19 and the resulting mitigation measures on food and eating in the east of England. Hertfordshire University, (NIHR ARC, East of England funded). The impact of COVID-19 on food systems and practices in the East of England

Part 2: Future Outlook

The first part of this report has considered the impacts on UK food and nutrition *during* the COVID-19 pandemic. The next section considers opportunities and alternatives *after* the pandemic by exploring future plausible scenarios and what this may mean in respect of trade, diets and behaviour, land use change and consequences on environmental health.

Key Findings: Future perspectives

Outlook – near-term (next 1-3 years):

- There are indications of sustained food prices increasing globally, which if coupled with economic downturn, will exacerbate existing inequalities between being food secure and insecure, both in the UK and globally.
    - Those people already experiencing food and nutrition insecurity in the UK due to economic access difficulties are likely to be even more at risk if prices continue to increase relative to income and available support.
- Differences in vaccination rates between countries and emerging new coronavirus variants such as Omicron may mean a potential phase of further COVID-19 waves in countries exporting food to the UK, which may increase shortages and exacerbate food price increases.
- The global food system has thus far been able to adapt to the pandemic, but care is needed to avoid entrenchment in a system that is not resilient to the longer-term threats from climate change, biodiversity loss and ecosystem degradation.
- Progress towards more agroecologically-balanced, lower input arable cropping systems will increase production resilience by reducing dependence on vulnerable input supply chains. However, whilst production efficiency should be enhanced, overall outputs are unlikely to increase so food imports are unlikely to be reduced.

Project Report Summaries:

The following sections summarises findings from four project reports focussed on the future:

Scenarios for UK Food and Nutrition Security in the wake of the COVID-19 Pandemic, James Hutton Institute. 20th August 2021 - Also available on Zenodo

Exploring COVID-19 Food and Nutrition Security Plausible Scenario Narratives with the 'FeedUs' Model of Global Food Trade. James Hutton Institute 15th October 2021.

Post-COVID-19 land use options to achieve food security, healthy diets and a sustainable environment. James Hutton Institute and Cranfield University. 12th December 2021

Exploring the effects on UK food security and land use of four scenarios describing socio-economic responses to COVID-19. Cranfield University and The James Hutton Institute 5th October 2021.

Plausible Scenarios

This section summarises the report Scenarios for UK Food and Nutrition Security in the wake of the COVID-19 Pandemic.

The future is inherently uncertain. However, we can look at both past events and the current situation, identifying themes and constructing patterns to promote strategic thinking. Scenario Planning utilises abductive reasoning in this way to yield plausible hypothesis. In contrast to deductive or inductive logic, there is no attempt to verify the projections. The plausibility test acts rather to harness human creativity and imagination in making plans that are robust enough and sufficiently flexible to deal with unpredictable developments.

This part of the project adopted an 'exploratory' scenario development approach, a method often deployed to stimulate creative thinking or to gain insight into the cascading effects of social, economic, and environmental drivers. Scenarios are crafted to form plausible accounts of what the future might look like by considering how known drivers of change will potentially operate over time. Exploratory scenario planning typically asks a focal question containing a time horizon. We selected the year 2030, a timescale sufficiently distant to get a strategic view looking beyond current operational concerns but staying within policy cycles and avoiding the science fiction associated with distant futures. We asked our scenario planners the following question:

What will food and nutrition security look like in the UK in 2030 given changes to the food system following the emergence of the Covid 19 pandemic?

Six overarching drivers of change were determined by the research team in a semi-structured interview guide. Drivers of change are forces that will shape the future environment. The six preselected overarching drivers are: Demographics, Economy, Public Health, Institutions & Governance, Technology, Ecology & Climate. Experts were invited to articulate specific challenges and opportunities in each of the six categories forming key drivers of change for our focal question. We recruited our expert scenario planners from areas relevant to Food and Nutrition Security including health, agriculture, aquaculture, and food systems. They worked with our bespoke, structured technique to develop four scenarios considering key drivers of change and their plausible impacts on the UK's food and nutrition security. Our 'virtual' process was developed to fully comply with the COVID-19 lockdown measures in force during 2020.

No one knows how or which drivers will influence events given that the future is inherently uncertain, however, scenario planning works by exploring different assumptions about how drivers of change may operate. Contrasting sets of assumptions frame the four, following scenarios.

Scenario 1 : 'UK Recovery First'

A national recovery at any cost has been achieved against the backdrop of recessionary pressures. Neither a radical green recovery nor any widespread levelling-up have occurred, resulting in higher food prices, negative Food and Nutrition Security outcomes for those on the lowest incomes and mounting societal unrest.

Scenario 2: 'Green UK First'

A domestic green recovery has achieved environmental improvements within a less globalised, more inward-looking world. Levelling-up has not been achieved and inequality alongside higher food prices has resulted in negative Food and Nutrition Security outcomes for those on low incomes.

Scenario 3: 'Best of British'

The UK has responded to greater protectionism by investing in UK agriculture putting quality at the centre but without any effective levelling-up, resulting in negative Food and Nutrition Security outcomes for those on low incomes set against higher quality produce for many others. Innovation and technology have helped the food sector to recover and prosper and there has been continuing consolidation resulting in larger farms and food businesses. Hospitality is radically reshaped around suburban spaces.

Scenario 4: Back to Basics

Economic recovery has been achieved within this, the most prosperous of the post BREXIT scenarios, featuring a return to globalisation and buoyant international trade. The return to the pre pandemic baseline has been an uphill struggle and neither Green Recovery nor levelling-up have markedly reshaped this unsustainable and unequal future.

Implications for UK Food and Nutrition Security

Our four scenarios describe plausible futures for the UK food system with a particular focus on food and nutrition security (FNS). The FNS concept is one developed by the United Nations Food and Agriculture Organisation (FAO) and rests on four conceptual pillars, namely Access, Availability, Utilization and Stability (FAO 2008). The following sections articulates the strategic thinking regarding these four pillars and presents the key ideas that emerged regarding cascading effects within and between scenarios.

Availability

Underpinning FNS is the basic requirement that sufficient food must exist in the first place. Our exercise identified challenges around greening the food system while simultaneously ensuring the delivery of sufficient food stocks. The restructuring of production systems to reduce greenhouse gases, partly by improving the carbon footprint of livestock, particularly in the uplands, restoring peatland, expanding afforestation, and going hard towards net zero targets, requires a corresponding effort in rebalancing the food system in terms of rewarding environmentally sustainable activities that deliver food. This balancing act already appeared precarious in the face of emergent post-Brexit trade relations. UK agriculture needs to find its way under future arrangements with trading partners new and old, and within a changed labour market. Covid-19 has potentially exacerbated the problem by diverting political energy away from wider health and environmental goals. Allowing climate change mitigation and domestic production support arrangements to slip down the agenda is fraught with danger.

Access

This pillar of FNS addresses the FAO concern that while food may be produced in sufficient quantities and available for consumption, it cannot deliver food security if it does not reach those who need it. People and food systems require adequate systems and resources to obtain appropriate foods for a nutritious and culturally suitable diet. To this end our scenario planners drew attention to the structural causes underlying people's choices about the food they eat and

how marginalised groups lack agency to effect change. Radical recommendations were put forward to combat food poverty and the recent escalation in the use of food banks. Foremost among the ideas to address the root causes of inequality was a proposal to significantly increase the national minimum wage. A more equal society, it was argued, could be constructed with relatively higher wages for the bottom tier of society thereby expanding choices and increasing access to more nutritious diets. It was acknowledged that the issues around high unemployment could not be addressed by in-work benefits but that, under other scenario conditions, FNS could be improved via such measures.

Other key recommendations concerned the need not to underestimate the extent of the health crisis that has been created. In all four scenarios a degree of optimism has been taken towards ending the pandemic through public vaccination. However, all four scenarios envisage an ongoing public health crisis deep into the coming decade. C19 has wrought havoc on medical systems and social care, and left a legacy of problems as each scenario imagines in a subtlety different way.

So-called 'levelling-up', whereby economically deprived areas of the UK are given a boost relative to more advantaged areas, was greeted with general scepticism throughout this exercise. None of the four scenarios foresee imminent structural changes whereby food and nutrition security for the less well-off is improved or levelled-up in the coming decade. Conversely, a widening gap features in all four scenarios. This rather bleak assessment rests upon a shared view that different forms of recovery all face an uphill battle of one sort or another that will militate against an increase social justice *vis a vis* the food system.

Utilization

Food must be prepared and consumed appropriately based on knowledge of basic nutrition and, food hygiene, alongside practical skills including handling and cooking, and cultural sensitivities. The pandemic has wrought changes upon the utilization of food in areas ranging from lockdown disruption of school meal provision to the severe restrictions on food outlets. Perhaps most alarmingly the use of food banks has grown as more people have been unable to purchase food due to changed economic circumstances. A potentially positive outcome regarding nutrition is that disruptions have led to an increase in home cooking.

Our scenarios variously reimagined the future foodscape as one in which a lower tier of UK society continue to experience food and nutrition insecurity. Positive dietary trends are anticipated, notably continuing flexitarianism in **UK Green Recovery First** and a generational shift in preferences towards local, seasonal, organic, vegetarian, and vegan food in **Best of British**, but in all four scenarios, the less well-off continue to struggle through lack of agency. Various proposals emerged throughout the exercise whereby education, information campaigns and economic incentives could be deployed to nudge or reshape social attitudes to nutrition. Our planners also highlighted food waste throughout the food system and recommended technology investment, specifically around both shelf-life and demand forecasting to improve the utilization of food stocks.

Stability

For the food system to be a dependable delivery mechanism for public goods in terms of healthy, high quality affordable diets in the face of future shocks it needs to be safeguarded against the vagaries of international trade in a sustainable way. Current fears around declining UK food

standards in the wake of a comprehensive new deal with the US are realised in **UK Recovery First** and avoided in **Best of British**. Much discussion centred around land use. **Green Recovery First** showed the potential for environmental gains without a radically improved food scape. Conversely, **Best of British** depicted a future in which more localised, more diversified production and consumption has been achieved within a more protectionist food system, yet without significant environmental gains.

Technological fixes are not viewed as a silver bullet to food and nutrition security. More advanced technological food systems, such as the UK system, face challenges that seem more connected to inequity than to technological shortcomings. Nevertheless, our planners saw technology as a part of the solution provided applications are directed towards appropriate goals, for example, reducing the environmental impact of water usage, increasing the use of renewable energy sources or shortening supply chains.

Scenarios: Concluding remarks

It is not possible to represent an exhaustive range of future possibilities in a complex socio-technical system such as the UK food system. Unanticipated factors or 'unknown unknowns' will shape the future beyond anyone's ability to foresee. However, what we have been able to do is to creatively use relevant expertise to think through 'what if' scenarios, or synthetic futures, considering plausible assumptions in a limited range of contrasting permutations.

UK food, diet and land options

This section summarises the findings of a study looking at how the UK's food production can align to enable development of a food system that better meets requirements for a healthy diet and a sustainable environment. The full report is available here: Post-COVID-19 land use options to achieve food security, healthy diets and a sustainable environment.

The COVID-19 pandemic has primarily been a demand side shock, with economic assess, particularly for those on low or newly lost incomes, causing food and nutrition security issues, rather than supply side shortages. The pandemic and post-EU exit recoveries present an opportunity to realign the food system with human health needs and sustainable, decarbonised production systems.

To investigate options, we used a set of four post-COVID-19 recovery and post-EU exit plausible future scenarios, developed as part of a wider UKRI funded project 'UK food and nutrition security during and after the COVID-19 pandemic', are used to frame the key drivers that may shape future food demand, production and consumption.

The context is that there is need, given the economic and social pressures brought about the pandemic, diet related health issues, climate change, biodiversity loss and ecosystem degradation, to transform the global food system. The aim of this study is to present information to support informed decision making on how the UK food system can transform to achieve multiple human and environmental health objectives.

The research approach is to first consider the potential for change in the UK agriculture and land use, on the basis that changes in UK food production will be highly dependent on the amounts and types of food imported. Import and export issues are addressed in a series of other reports

produced by the 'UK food and nutrition security during and after the COVID-19 pandemic' project funded by the UKRI and ESRC.

The key findings were:

- There are sufficient land resources available in the UK to enable food production that aligns with a healthy diet.
- Changes in UK land use and food production to achieve a healthy diet can also reduce the environmental footprint.
- Changes in land use and types of food produced needed for human and environmental health will require substantial changes to the food system in respect of consumer behaviour driving market demand.
- Transformation of food production will have consequences on rural communities, socio-economics and business practices, with both risks and opportunities.
- **Food groups and healthy diets:**
    - Recommendations exist on the types and proportions of foods and drinks needed for a healthy balanced diet, such as Public Health England's Eatwell Guide, that can be used to identify opportunities for changes in land use and food production.
    - Moving from current to the recommended patterns in the Eatwell Guide requires more energy to be derived from carbohydrate and protein, and less from fat. The proportion of simple sugars in consumed carbohydrates should be halved, salt consumption should be reduced, and fibre consumption increased.
    - A move to healthier diets is expected to increase the demand for milling wheat, vegetables and fruits, with declines for beef, pig meat, sugar, and milk. If these changes occurred, they would affect the level of UK self-sufficiency for these products.
    - The COVID-19 pandemic has led to a "K" response in the consumption of healthier food: some people have healthier diets; many people have had a less healthy diet. For example, about 30-40% reported eating more confectionery, biscuits, and cakes compared to about 15% who had eaten less. Because unhealthy food is typically cheaper than healthy food, financial insecurity leads to less healthy diets.
- Risks and opportunities of aligning food production to demand:
    - To increase production to match demand more closely for those commodities already produced in the UK, while at the same time adjusting to aligned production with diets that are healthier for humans and the environment, will have consequences for land use, farm inputs, and income.
    - Overall, moves towards self-sufficiency, healthy diets, and the reduction of GHG emissions favour reduction in meat and dairy, as well as cereals because of a decline in demand for livestock feed. Potatoes and horticultural crops (fruit and veg) would see substantial increases in production.
    - The combined impact of these changes would be to reduce the demand for land, both pasture and arable (down by as much as 26%) and reduce nitrogen application by up to 23%. Pesticide input would increase substantially (up to 58%) and the shift in commodities would results in increase in income by as much as a 28%.

- Post-COVID-19 Green Recovery scenarios offer a way forward that tackles climate change and diet related ill-health while also offering greater production efficiency. However, the changes in the livestock and horticulture sector would demand significant structural changes to the UK agri-food system.

- **Impacts of agroecological farm practices.**
  - Sustainable production of food in the UK requires a transition to agroecological practices where the farmed environment is managed for provision of multiple benefits in terms of both crop production and the environment.
  - Agroecological farming is based on functional biodiversity which is utilised for: a) internal system regulation and increased production efficiency which together reduce reliance on agrochemical inputs, and; b) enhancing resilience through functional redundancy, thereby insuring against future shocks and improving yield stability in the long-term.
  - The capacity for UK farming to benefit from agroecological practices, in terms of long-term sustainability and resilience to future disruption, depends on the extent to which transition is supported following Brexit and in the aftermath of the covid pandemic.
  - A "build back greener" recovery, with incentives for crop diversification, soil health and biodiversity management is most likely to deliver the opportunity to transition to more sustainable agroecological production systems in the UK with the potential to meet demands for a more diverse range of home-grown food products.

- **UK capacity for protein self-reliance.**
  - The capacity of production of high-protein plant grains, and vegetative material, is high, though not realised in practice due to the availability and affordability of imports, despite the high environmental costs of those imports, and loss or/and non-development. of national capacities.
  - Animal and aquaculture feed markets present largest demand for home-grown plant protein. Particularly pig and poultry production, such that only a very small percentage of UK grown plant protein is sold to higher premium more lucrative human food markets – and despite the potential human health and well-being benefits. Also, reduced NHS cost burden.
  - There is a lack of national capacities to process high-protein plant material to human food grade. National food security should ensure a bio-regionalised approach, such that functionally equivalent capacities are strategically developed across regions of the UK.
  - Home-grown legume-based food systems have the capacity address food and nutrition security matters, and other major society challenges such as climate change and biodiversity loss. This can be achieved without jeopardising productivity with the proper facilitative environment in place.

- New Technology opportunities for Controlled Environment Agriculture:
  - The infrastructure of Controlled Environment Agriculture / Vertical Farming (CEA/VF) is evolving and improving at a significant rate and largely driven by industry meaning that the outputs have been developed on commercial foundations.
  - The energy input conundrum for CEA/VF is capable of being resolved and that better links to (renewable) energy generation and management sectors need to be forged.

- The next step change for CEA/VF food production is likely to be biological as we look to redesign the crops to suit the growing environment as we have done for traditional agriculture.
- At the lower technology readiness level, is the production of laboratory or cell culture-based meat which requires very defined levels of controlled environment.
- Laboratory meat, like crop CEA/VF systems, is attracting significant investment and due to the significant contribution of livestock production to GHG emissions could potentially offer routes to low or net zero meat.
- Other opportunities include insect production for protein, oil etc

Post-COVID-19 Green Recovery scenarios not only offer a way forward that tackles climate change and diet related ill-health but also offer greater production efficiency by increasing the income generated from agricultural commodities while simultaneously reducing the required land area. Structural changes would be significant with a reduction of the livestock sector by up to 66% and an 164% increase in horticulture driving a 158% increase in pesticide use, although other inputs (e.g. nitrogen) would decline. However, the increased production efficiency could provide scope for innovations in crop, livestock, and other land use strategies to address negative socio-economic and environmental aspects of agricultural transition.

UK infrastructure for the processing of plant protein to human food grade is lacking. Where it does exist, this is to serve mainly animal food markets. Even the limited quantity of high protein grains destined for human food consumption is exported. There is an urgent need to develop bio-regionalised plant-protein facilities so that an array of equivalent capacities is developed and maintained strategically across the UK. The creation of such a capacity would accommodate the necessary functional redundancy to allow food system resilience in the face of system shocks. Additionally, this would demand that protein import dependency is maintained below a threshold level (to be decided). Also, that storage facilities are also re-established nationally regionalised basis, for high protein-grains, or -isolates.

Land use and environmental health responses to changes in trade.

This component of the project used a spatial land use model responsive to socio-economic and technological drivers to explore trade-offs between UK agricultural yield improvement, food and timber security, bioenergy, net import levels, and targeted increases in tree cover. The full report is available here: Exploring the effects on UK food security and land use of four scenarios describing socio-economic responses to COVID-19.

Key findings:

- Increasing net food imports create beneficial environmental effects in the UK, but negative offshore effects.
  - There is need to undertake Life Cycle Analysis to understand the trade-offs at a global scale.

- Top-down targets for high levels of bioenergy production on agricultural land and reduced fertilizer use reduced the release of land for afforestation.
- Methods to reduce UK meat consumption increases alternative options for land use.
- On the basis of the opportunity costs of land, increases in tree cover are easiest to achieve in Wales, Northern England, and southern Scotland.
- Soil function indicator modelling indicated that some scenarios of future land use in the UK have markedly more positive impacts on soil functionality than others. These impacts appear strongly linked to increasing or decreasing net food imports.

The way that the UK Government and others respond to the challenges of COVID-19 recovery and Brexit will have major effects on the UK food system and land use. Using a spatial modelling approach we examined the effect of the four contrasting plausible scenarios (detailed above) on UK land use and food security, using the IAP2 European-scale land allocation model. The scenarios were assumed to apply to both the UK and the rest of Europe.

Assumptions regarding the level of food imports and the increase in agricultural yields have a major effect on land use in the UK. A trade liberalisation scenario, called Back to Basics and assuming a 10% increase in net imports and increased agricultural yields (+10% from 2020 to 2030), enabled the supply of agricultural and forestry products to match demand, and provided opportunity for greater afforestation in the UK (+5.5%). However increased negative environment effects are anticipated from increased food and timber production outside Europe and associated logistics costs such as transportation, storage, and refrigeration. The UK Recovery First scenario, assuming no change in net imports but similar increased yields also enabled afforestation albeit at a lower level (+2.3%).

The results highlight that enabling increases in agricultural yields and maintaining current levels of food, feed and timber imports to the UK creates opportunities to release land for tree planting without undermining food security (Figure 7). In 2019, the UK imported the equivalent of 45% of its food (based on farm-gate prices of unprocessed food) (UK Government 2020). In view of the

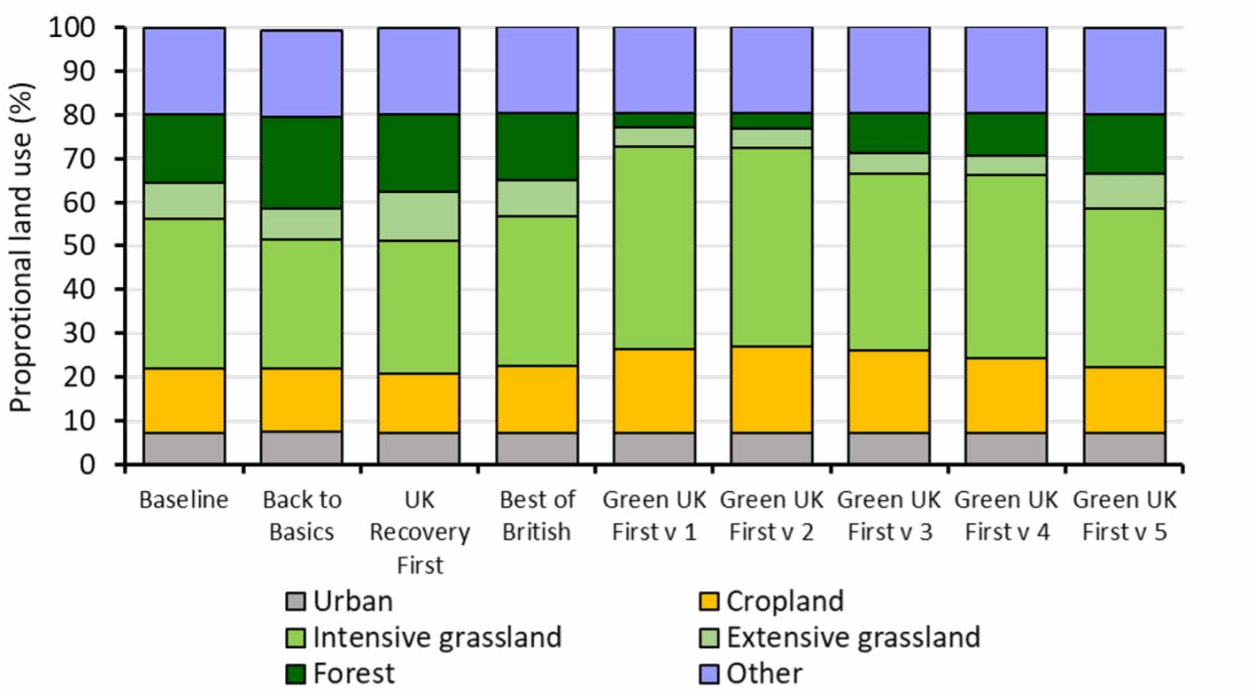

Figure 7. Predicted proportional land use in the UK for the 2020 Baseline scenario; the Back to Basics, UK Recover First, and Best of British scenarios, and five versions of the Green UK First scenario

target to achieve net zero greenhouse gas emissions by 2050, the UK Government is planning a net increase in tree cover in excess of 30,000 ha per year by 2025 (UK Government 2021). If this target is achieved over 10 years, the area of 300,000 ha represents a net land use change of 1.2%. Such increases in tree cover are predicted as possible under the Back to Basics and the UK Recovery First scenarios.

Scenarios involving a reduction in net imports reduced the availability of agricultural land for other purposes. Using the IAP2 model, the Best of British scenario, which assumed a 10% reduction in net imports and an allocation of 10% of the arable area to bioenergy, was predicted to result in a small decline in woodland area (-0.4%). The Green UK First scenario added additional constraints of no increase in agricultural yields, a requirement for 5% of arable land to be used for conservation, and reduced fertiliser use (-26%. Note: the assumption here was the use of synthetic fertiliser decreases to reduce GHG emissions and does not reflect the current trajectory of utilising fertiliser equivalents such as digestates). Whilst this scenario was able to match the supply of crop and milk products to demand, there was a shortfall in meat (-25%) and timber supply (-54%), and the drive to maximise food production (in the absence of other constraints) was predicted to result in the conversion of woodland (-12.5%) to grassland (+12.2%). Matching supply to the demand for meat and 81% of the demand for timber was possible by reducing the demand for meat by 30%, the area of bioenergy crops and conservation area on arable land to zero and maintaining current fertilizer application rates. The results highlight the real trade-offs between a lack of yield increases, increasing use of agricultural land for bioenergy, reduced imports, reduced fertilizer use, current meat consumption levels, increases in tree cover, and food and timber security.

Environmental quality: Using soil function indicators, we also highlight how land use changes that may occur under the four scenarios, either positively or negatively impact key environmental benefits supported by soil (carbon storage, primary productivity, water supply, nutrient availability and pollination). Each scenario produces a range of spatially explicit impacts on these soil functions across the UK, with none being 'all positive' or 'all negative'. The Back to Basics and UK Recovery First scenarios are overall more positive in their predicted impacts than the Best of Britain and Green UK First scenarios. Each region sees a variation in land use change impacts across the scenarios, with most regions having some 'mostly positive' and some 'mostly negative' consequences.

Whilst grassland in generals occupy different climatic and topographic regions in the UK to arable cropping (colder, wetter areas and steeper slopes are less appropriate for arable cropping but can be suitable for grassland), there is significant overlap in occurrence. Additionally, there are many parts of the UK where grassland currently dominated but that would be suitable for arable crops (Northern Ireland is a good example). A shift in land use from grassland to arable cropping implies an increase in ploughing rate and other management activities that are disruptive to soil organic carbon stores. As grassland contains more carbon than arable land, this means that any such shift in land use will lead to a loss in soil organic carbon and an associated increase in soil-based GHG emissions. At recommended UK livestock numbers per unit area, GHG emissions from cattle on grassland are estimated at approximately 1.4 tonnes CO_2eq per hectare per year. A reduction in soil organic matter from 10% (a reasonable estimate for grassland) to 3% in the top 30 cm of the soil for arable cropping over a period of 50 years (a conservative estimate for rate of change) would produce GHG emissions of 5.7 tonnes CO2eq per hectare per year, over 4 times what would be emitted by maintaining a grazed system. Therefore, if grassland to arable cropping transitions are

proposed at any location, there are questions to be answered as to how this can be justified in relation to GHG emissions.

In the context of post-pandemic recovery to maintain the UK's food and nutrition security, these results highlight the complexity of balancing objectives from multiple pressures including trade negotiations (affecting imports and exports), improving diet, climate change mitigation (reducing fertiliser use, producing bioenergy, woodland creation) and maintaining healthy soils and ecosystems.

Conclusions: The use of a spatially-explicit integrated land use model, that is able to respond to a range of socio-economic drivers, provides a useful way to sense-check four scenarios developed as part of a food and nutritional security study. It also provides opportunity for expert judgement to inform model inputs. The analysis indicated that increasing the level of food imports can reduce the pressures on land use in the importing country, but it is anticipated that negative environmental effects will occur elsewhere. These have not been quantified in this study, and if a country is to pursue the objective of increasing food imports, then it would be responsible to undertake a global life cycle assessment of the probable effects. Methods of increasing agricultural productivity per unit area without increasing negative environmental effects are particularly attractive and should be a focus for research and extension. The study highlights that a drive for greater food sufficiency in the UK is likely to lead to major economic and environmental trade-offs either in terms of food security or the availability of land for expanding tree cover. The study also shows that the use of agricultural land for bioenergy production could cause perverse outcomes such as increased pressure to convert wooded land to farmland. As reported elsewhere, if a UK food policy uses greener methods where yield increases over currently conventional practices are not expected, then reduced meat consumption per capita can be useful in matching food demand and supply. Scenarios that reduced food production in the UK in favour of imports were modelled to have the strongest positive impacts on UK soil function.

Global trade modelling – FeedUs

This section presents results from the use of an agent-based model 'FeedUs' (Ge et al. 2021) on modelling international trade, providing information to inform discussion on how land use and management in the UK for food production may be impacted.

The full report is available here: Exploring COVID-19 Food and Nutrition Security Plausible Scenario Narratives with the 'FeedUs' Model of Global Food

The objective was to assess the plausible scenarios in respect of impacts on the quantities of different food types imported to and exported from the UK, and which countries the UK trades with were more likely to be affected. FeedUs simulates countries as agents, who trade the food they have produced in order to meet the nutritional needs of their populations. The role of FeedUs in this project was to see how interpretations of the project's co-constructed plausible scenario narratives for food and nutrition in the wake of the COVID-19 pandemic (Duckett, 2021) affected the goods traded and countries traded with for the United Kingdom.

The purpose was not to be predictive (as there are too many unknowns and assumptions) but instead to generate information to help inform discussion and consideration of the multiple consequences of changes in key national and international drivers affecting the UK food system. The model was run for the period 2000-2030 (baseline 2000-2020).

Key findings:

- The four plausible scenarios explored result in different impacts on food imports in terms of types and where these originate from in respect of the countries we trade with. Though not explored here, these impacts can be anticipated to have cascading consequences:
    - Changes in the balance of imports and exports will have consequences on food and nutrition security in respect of those on low incomes due to potential prices changes
    - The scales of the estimated changes will have significant consequences in terms of environmental impacts in the UK due to changes in land use to meet demand, and in exporting countries (with potentially negative impacts due to lower environmental standards).
    - Estimated changes will have consequences on the balance of trade between the UK and other countries and our trading relationships with them. Each scenario explored implies a changing dynamic with our trading partners.
- The results provide insights that will be informative in considerations of the trade-offs between increasing UK production versus changing the amount and types of foods imported, and from where, in respect of food security and environmental health.

The results show some consistent patterns with respect to the goods and countries most affected by each scenario. If there is a surprise, it is that the sign, rather than the magnitude, of change is more likely to differ from one scenario to another. The four plausible scenarios were compared against a baseline.

Scenario 1: UK Recovery First

The Recovery First scenario has small increases in imports from Armenia, Ireland, Portugal and Thailand, with roughly 10% reductions in imports from many of the larger volumes of imports in the baseline scenario, especially Germany, the USA, New Zealand, The Netherlands, Australia, and Belarus. Larger proportional reductions are also present for countries with smaller volumes in the baseline, such as New Zealand, Latvia, Slovenia and Poland. The largest single reduction in import is for milk, which is reduced by approximately 50%. Note that while there is little trade in milk globally, there is significant trade in milk products (such as cheese) (Uberoi 2021), and the FAO's Food Balance Sheets category "Milk – Excluding butter" encompasses a wide range of milk products (including cheese, yoghurt, condensed milk and ice cream).

There are increased exports, especially to Russia and Pakistan, but China, Saudi Arabia and Viet Nam also feature notable increases. As well as the main exported products in the baseline, poultry meat is increased. The general pattern of change is similar to Back to Basics.

Scenario 2: Green UK First (V1 – V4/5)

For this scenario a set of four different parameters were used. For V1 there is a general pattern of increased imports, especially from the countries with larger volumes of imports to the UK in the Baseline scenario. In a notable contrast with the Back to Basics, Recovery First and Best of British Scenarios, there is a large increase in the volume of milk imported (a little under 50%); further, the four products with the largest increase in imports in Back to Basics (maize, rice, wine and

soyabeans) are the four with the largest decrease in this scenario. Another significant contrast with the non-green scenarios is that all exports have decreased in volume, especially to Mexico, India, Russia and Ireland, and for the three products showing the largest increase in the non-green scenarios (rape, oats and poultry meat). Other versions show variations on V1 reflecting changes in demand for products and associated changes in imports and exports.

Scenario 3: Best of British

The pattern is broadly similar to that observed for the Back to Basics and Recovery First scenarios: the largest reductions in imports being for milk, and from countries with which the UK has generally larger volumes of import in the Baseline scenario. There are also similarities in exports with respect to countries and products. The main notable differences with Back to Basics and Recovery First are that the Netherlands, which had a reduced change in volume imported to the UK in Back to Basics and Recovery First, has an increased volume in Best of British, while Mexico, which had the largest change in export volume in Back to Basics, and a positive change in Recovery First, has almost zero change here. The magnitude of the change is also generally smaller for foods, especially for imported milk, which is about 50% smaller (about 25% reduction in comparison with the Baseline).

Scenario 4: Back to Basics

In comparison with the Baseline scenario, the Back to Basics scenario features increased import volumes from Italy, Paraguay and India especially, but reduced imports mostly from EU countries (Germany, France, Latvia, Slovenia, Poland, Czechia, Lithuania, The Netherlands and Hungary), but also from Belarus, New Zealand, Canada and Australia. Though there are small increases in imports of maize, wine, rice and soyabeans, there is an especially large reduction in the volume of milk imported (around 50% of the Baseline volume). The largest volumes of change in exports are increases to Mexico, Pakistan, China, Saudi Arabia and Viet Nam, with larger volumes of change associated with rape and mustardseed, poultry meat and oats.

Increased global trade

Increasing the proportion of possible global trades enabled by the model leads mainly to increased imports of barley and wheat, with higher volumes of import especially from Canada, Ukraine and Russia. Perhaps unexpectedly, it also leads to slightly reduced exports of beef. This may be explained by countries that would have prioritized the UK more during trading rounds (presumably Tanzania) having greater opportunity to fulfil their demand for beef from other countries (e.g. with lower GDP). There are small increases in exports to Slovakia, Belgium and Germany.

Decreased global trade

Decreasing the opportunities for global trade leads to reductions in imports of wheat especially, with smaller reductions in imports of barley. The UK buys less from many of the countries from which it buys more: Ukraine, Russia and Canada especially. Exports are also reduced, with oats featuring in the reductions as well as beef reductions observed when opportunities for trade are increased.

Recommendations

The pandemic and its consequences have provided a unique opportunity for governments and businesses internationally and in the UK to pause and reflect on the concerns and issues on the current food system and what a sustainable and resilient one might be like in the future.

The following recommendations are made in the context of known projected pressures arising from climate change (extreme events and trends), biodiversity loss and ecosystem degradation set against a background of an increasing human population with greater affluence and consumption demands.

These recommendations have been compiled through project team members and engagement with stakeholders through workshops held as part of the research project.

1. **Improve Prevention and Preparedness: there is need for the UK Government, businesses and society to improve preparedness to future impacts on the food system.**
    a. Need to improve awareness of different types of shock and consequences on scales of vulnerabilities, levels of exposure and types (sources) of threats (economic, climate, environmental) and understanding of direct impact risks and cascading consequences.
    b. Invest in capabilities to improve foresight and response preparation, e.g. scenario planning. modelling.
    c. Improve the culture of contingency planning and preparedness within governance to plan for single and multiple synchronous extreme events as well as long-term change.
    d. The level of preparedness needs to be commensurate with the probability and scale of risk and severity of potential impacts.
    e. Utilise horizon scanning, cross-sectoral scenario planning and modelling to explore cascading risks and opportunities for mitigation and adaptation.
    f. Develop a better understanding of how different types of shocks cascade through the food system and propagate food insecurity. There is need to better understand and model the food system connectivities and interdependence to be able to identify critical pinch-points and vulnerabilities and to explore alternatives for preparation before a shock occurs.
    g. Identify a range of land use scenarios that meet multiple objectives of healthy diets, net zero greenhouse gas emissions (particularly from land use change), sustainable ecosystems and viable businesses.
        i. Aim to reduce dependencies on international supply of proteins for animal feed through increased domestic production and reconfiguring fodder requirements.
        ii. Improve UK ‘s ability to produce fruits, vegetables and proteins. Care is needed not to replace systemic risks (arising from import vulnerabilities) with idiosyncratic localised ones. There is a need to improve the risk mitigating role of international supply, through less geographical concentration and more investment in resilience of production environments.
    h. Work with key food system stakeholders to develop adaptable contingency plans and associated required actions that can be rapidly implemented to minimise impacts.

i. Update contingency plans and communicate preparation and response strategies in advance to help facilitate rapid implementation and stabilise market fluctuation responses.

j. The pandemic has shown it is possible to implement difficult policies when the risks and consequences of not doing so are clear to the public. There is a need for greater awareness raising of future risks in order to facilitate acceptance of policies developed to make the food system more sustainable and resilient.

iii. There is need for the Cabinet Office to better understand competing policy priorities and how coherent, synergistic policy responses can be developed.

2. Reduce inequalities: there is need to improve support for vulnerable people.

a. Income support for people on low-income is more likely to reduce risks of increasing food and nutrition insecurity given the potential rise in global food prices.

b. Inequalities in food and nutrition security are a result of many contributing socio-economic factors acting alongside a food system that externalises the health and environmental costs.

i. There is need for policies to be developed that strengthen safety nets during shocks to the food system to help avoid food poverty that need to be structured to ensure healthy nutritious food is acquired.

ii. There is a need for a range of measures to promote healthier diets including nudges, policy initiatives, educational programs and community schemes.

iii. Giving people more economic resources and more time to access food is needed to bring about a change in attitudes towards healthier diets. Increasing available time and money gives people more agency to acquire knowledge for improved food utilisation.

c. There is need for improved comprehensive monitoring and tracking of food insecurity, especially amongst the most vulnerable, and between genders and ethnic minorities.

d. When shocks occur, schemes are needed that can be rapidly implemented to ensure guaranteed access to sufficient nutritious food for a healthy diet for all members of society, particularly the most vulnerable, when shocks occur.

e. Support physical access for the most vulnerable through improved mobility or home delivery.

f. The role of the Third Sector needs to be supported more to help ensure those most exposed to food insecurity are better protected.

g. There is need to develop strategies to manage how and when reductions in retailer promotions (withdrawn) are implemented, as this can influence grocery inflation rates and limit access to cheaper food by those on low incomes.

3. Develop a sustainable recovery response: Global and UK Government and business strategic responses to post-pandemic recovery should;

a. The UK, as it seeks to assert its post-Brexit 'Global Britain' narrative, must position itself both internationally and domestically in the vanguard of supporting and enabling post-COVID food systems that forestall short-term food insecurity concerns and that promote long-term nutritional, livelihood, and environmental security.

b. Aim to achieve improved food and nutrition security for long-term human health benefits

and environmental sustainability. This requires an improved rebalancing from the current focus on efficiency to one of resilience. A sole focus on efficiency or resilience will be problematic: there is a clear need for efficiency but not at the expense of resilience.

i. Increase the diversity of food types and how they are produced rather than rely on a small number of crops, facilitate more diverse food markets including localised systems, diversify farm systems for multi-functional landscapes.

ii. Buffer the food system to shocks by reducing dependency on the 'just-in-time' strategy and incorporate greater redundancy (i.e. through greater storage capacity) and flexibility (ability to switch between suppliers, food types).

iii. Improve UK diets for human health that also benefit the environment, with greater use of plant-based proteins, whole grains and less meat and highly processed calories.

iv. Develop low waste systems and circular economy-based use of residuals.

c. Care is needed to ensure post-Brexit trade deals do not exploit food exporting countries where slow vaccination programmes mean potential further COVID-19 waves.

i. Need to ensure trust in trade is maintained in case of further global food price rises.

1. Improve transparency in trade data i.e. AMIS trade reporting.

d. Aim for environmental standards equivalence to reduce ecosystem impacts, i.e. through the Trade and Agriculture Commission, which needs to be adequately resourced to enable it to take a central role in UK trade governance and oversight.

e. Maintain international cooperation on trade to prevent export restrictions.

f. Integrate food system realignment for human health and environmental sustainability goals to with parallel objectives of the Sustainable Development Goals, including poverty reduction, greenhouse gas emissions reduction, ecosystem restoration and biodiversity enhancement.

4. **Transform the Food system:** The current food system is highly centralised, which may have helped in terms of maintaining functionality during the pandemic, but may be vulnerable due to fragility arising from longer-term sustained risks (climate, biodiversity loss and ecosystem degradation). To build resilience in the food system, there is need to:

a. Enable functional redundancy by changing the focus on system resilience rather than efficiency.

b. Increase food system diversity.

i. There is need to change the focus from a concentration on a small number of grain products (wheat, rice, Maize, soy) to a wider diversity of crop products.

ii. Businesses need to avoid single point of failure risks and derive income from multiple products and pathways.

iii. There needs to be greater flexibility and substitutability in supply chains to buffer against shocks.

5. **Build resilience to future shocks,**

a. Increase storage capacity, particularly for fresh produce.

b. Decentralisation/modularisation and diversification of supply chains

c. Develop greater flexibility in reconfiguring supply chains, as well as greater capacity and responsiveness within social protection measures for producers and marginalised consumers.

d. Facilitate greater fruit and vegetable production and diversification of crops grown as part of the replacement of the Common Agriculture Policy.

e. Increase the focus on influencing consumer behaviour and the demand side function based on better informed choices on food environmental footprint and diet quality.

f. To improve nutrition security, there is need to improve the focus on proteins and affordable access to fruit, vegetables and nuts.

g. There is a good opportunity to improve local production and consumption to reduce environmental impact and help build local diversity and resilience.

    i. Controlled Environment Agriculture ('Vertical farming'), urban horticulture and large-scale community gardens present opportunities for localised food production with reduced environmental footprints and community social benefits. A better understanding is required as to what the overall total environmental benefits are.

    ii. The responses by local communities and the third sector to the pandemic has illustrated that there is strong Social Capital on which food system transformations can be built.

h. Ensure that shifts to a resilient and sustainable food system does not impact the most vulnerable, hence policies developed to enable transformation needs to be socially just and align with recommendations in Point 2 above.

6. **Understand better the relationships between changes in imports and exports and consequences on UK diet and land use.**

    a. There is a complex set of dynamic relationships between land use and human and environmental health within the UK and globally which are strongly influenced by the balance between imports and exports driven by consumer demand.

        i. There is need to develop the National Food Strategy to better integrate objectives between maintaining global trade whilst reducing environmental damage, improving diet and human health in the UK and understanding how these changes alter the land use and ecological impact.

        ii. There is a risk that adjustments to land use driven by changes in imports (e.g. as result of Brexit and trade deals) in conjunction with continued consumer demand and

7. **Spatial transformation needs: Integrate food system transformation with the need for multi-functional landscapes and marine environments.** The next 3-4 decades will place increasing pressures on terrestrial and marine ecosystems in respect of them needing to provide multiple benefits of ecosystem services, particularly climate regulation (carbon sequestration and storage) whilst underpinning food security, maintaining rural and coastal communities and supporting societal wellbeing. To integrate food system transformation in the UK with the need to enable multi-functional landscapes and marine environments we recommend:

    a. Improve research understanding of the priorities for what land is best used for from both economic and environmental perspectives and prioritise the trade-offs this presents.

i. A core principle for setting priorities should be that environmental health takes precedence over financial profit.

b. Improve the capacity to understand land capability for providing ecosystem services, agricultural and forestry productivity (and other land uses) and how climate change will impact that capability.

8. **Global and UK Government and research to improve knowledge:**

a. Improved and integrated climate-crop response, disease outbreak monitoring and modelling to identify production shock risks early (i.e. assessing teleconnection impacts of El Niño - La Niña events and other phenomena).

b. Understand what can be changed in the food system within biophysical capability boundaries (what land and see can provide) and the economic and socio-cultural barriers that need to be overcome.

c. Improve integration of global and UK datasets on production and trade (imports and exports) and forecasts to provide clearer real time indicators of production, stocks, demands and prices. The current emphasis of statistics presentation is on economic value, not food and nutrition security functional value.

i. There is need for better data on the nutritional functional value of food trade, rather than on monetary value and volume. Nutritional value data, including micro- and macro-nutrients, should be made available as part of trade statistics.

ii. Improved monitoring of food production, reserves and supply globally will help identify risks, bottlenecks and pressure points.

Conclusions

The purpose of this study was to provide input to discussions on the challenges of developing a resilient and sustainable food system that is capable of enabling greater food and nutrition security. The COVID-19 pandemic has provided a substantial global-scale shock to the world's economies and food system, yet the system has maintained supply, meaning the UK as a whole has not become food and nutrition insecure. The impacts have however increased food and nutrition insecurity for the most vulnerable members of society, who have experienced greater economic and physical access difficulties and a decrease in diet quality. Conversely, diet has improved amongst those that have not experienced economic access difficulties. This dichotomy reflects an increasing inequality divide, not just in food and nutrition security, but in wider social justice issues. Future shocks due to climate change biodiversity loss and ecosystem degradation will likely further exacerbate inequalities.

We have presented research findings that indicate that, despite substantial disturbances to the food system, the scale of the shock may not be sufficient to drive wholescale changes. This risks the misconception that the food system is resilient. In its current form and in the face of growing pressures from climate change, biodiversity loss and ecosystem degradation, and in the context of a growing more affluent population (but still with too many experiencing hunger), it is neither

resilient nor sustainable.

In learning lessons from the pandemic, there is need to recognise several incontrovertible truths:

1. The food system, by contributing to climate change from greenhouse gas emission (34% of global total) and environmental damage arising from land use change and unsustainable production practices, is thus the cause of threats to itself.
2. The costs of these negative impacts are not internalised within the food system, hence there are few direct feedbacks to drive reductions in damaging practises. The negative impacts of the food system are a market failure.
3. There is need for a large-scale shift in consumer behaviour to drive new demands that changes the food system in terms of what is produced, where and how. Policies that encourage healthy diets and discourage unhealthy ones through pricing (higher for those that decrease human and / or environmental health) and labelling (to inform consumer choice) must be part of the process to facilitate the shift.
4. We need to consume less meat and more fruit, vegetables and fibre (roughage). The scale of changes means there needs to be a substantial shift in land use and management practises.
5. Transforming the food system to become resilient will force hard choices to be made on how land is utilised, given necessary objectives for land to provide multiple benefits, particularly ecosystem services. This is likely to increase tensions between different stakeholders who may see changes as threats or opportunities.
6. There is need for greater public debate about the role of the food system within society. Given its essential role in enabling individuals and society to function and undertake economic activity, and yet cause human and environmental health problems along with large social inequalities, we need to question whether it is appropriate to have a system that is focussed on efficiency and profit before wider societal and environment benefits.

Looking positively at the situation, it is possible to achieve multiple benefits for people and the environment by transforming the food system. In this project, our use of plausible scenarios, applied to a range of modelling approaches to consider re-alignment of food production for healthy diets and environmental improvements, has shown it is possible to produce food in sufficient quantities and nutritional quality and contribute to environmental goals.

The main conclusion from this project to achieve these multiple benefits, in light of lessons learned from the COVID-19 pandemic, is the need for preparation and contingency planning with national food system strategies and internationally agreed measures to protect food and nutrition security. Fundamentally, prevention, in the form of reducing climate risks through deep and rapid mitigation and well-resourced support for adaptation in the food system, integrated with the reversal of environmental damage through sustainable production methods and ecosystem restoration will help progress towards protecting food and nutrition security against future risks.

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Please note: further, more comprehensive references are available in each of the project reports.

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