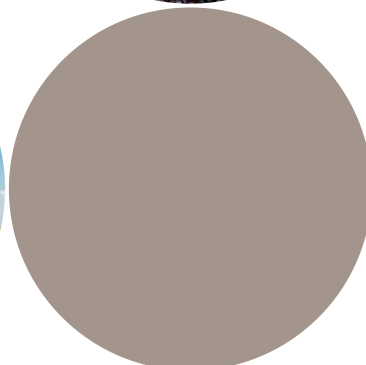
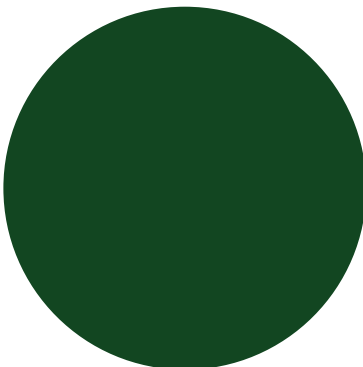


Global Food Security Strategic Plan



Contents

Foreword	2
1. Executive summary	3
2. Introduction	5
3. Vision	6
4. Context	6
Global food security drivers and challenges	7
5. The Global Food Security programme	10
Operating principles	10
Partners and affiliates	10
Added value of working together	11
Programme governance and management	12
Delivering impact	13
Monitoring progress	16
6. Research Themes	17
Theme 1 Resilience	18
Theme 2 Sustainable production and supply	20
Theme 3 Nutrition, health and wellbeing	23
7. Future priorities	26

Please note: references in this document are hyperlinks and can be accessed using the online version.

Global Food Security is a multi-agency programme bringing together the main UK public sector funders of research and training related to food. For further information and updates see the programme web site:

www.foodsecurity.ac.uk

Foreword

The need for change

I warmly welcome this new Global Food Security Strategy for increased coordination and collaboration on food-related research. This is a time of unprecedented demand for innovative solutions to sustain the flow of high quality food to more people than ever.

The food system is under increasing pressure to achieve secure supplies and to meet high standards of nutrition, safety and availability for a growing population with changing diets. At the same time the food system is responsible for around one third of greenhouse gas emissions. It is clear that the agri-food sector must adapt now to address these challenges, which affect us all, and support the Sustainable Development Goals and ambitions of the COP21 Paris Agreement to limit global warming to below 2°C.

Tackling these challenges will need coordinated action with a global focus, underpinned by excellent research, innovation and knowledge exchange to maximise impact. The UK's world-class reputation for scientific excellence has an essential role to play in making the step change in research and innovation needed for this systematic change.

As the UK prepares to leave the European Union, this presents opportunities for funders and stakeholders to adopt new approaches to how they work together. A key priority is linking research more closely with innovation and supporting research that can make the biggest difference in a short timeframe.

The Global Food Security programme provides a unique focus for funders, industry and the third sector to work in partnership to bring together multi-disciplinary research with maximum impact, and stimulate the innovation we need to tackle these challenges across the food system.



Professor Ian Boyd

Chief Scientific Adviser at Defra

1. Executive Summary

The UK's main public funders of food-related research and training are working together through the Global Food Security (GFS) programme. The programme aims to help meet the challenge of providing the world's growing population with a sustainable and secure supply of safe, nutritious and affordable high quality food. That food will need to be produced and supplied from less land and with lower inputs, and in the context of global climate change, other environmental changes and declining resources. The programme aims to provide evidence to enable food producers and processors, retailers, consumers and government to respond to and manage the challenges facing the UK food system and related global issues, including the many challenges confronting the developing world in the face of environmental and demographic change.

The political, scientific, and funding landscapes in which we operate are evolving. Following the outcome of the EU referendum, there will be an increasing need for evidence on how we might replace the Common Agricultural Policy to ensure positive outcomes for farming, the UK economy, health and the environment. Evidence will also be needed around how we maintain the UK's food security, including understanding the optimal balance between imports and exports, effects on the availability of different foods and public expectations around this, and new opportunities for trade and inward investment. With its recognised strength in world class science, innovation and interdisciplinary research, the UK is well placed to be the global partner of choice and this will provide new opportunities for collaborative, interdisciplinary research and development.

The food security challenge is also evolving – globally there are now more people who are obese than underweight; the UN's Sustainable Development Goals (SDGs) have been published with a focus on sustainable production and consumption alongside ending poverty and hunger; and there was agreement at the Paris Climate Conference (COP21) to aim to limit global warming to 1.5°C and to keep it well below 2°C. Reducing greenhouse gas (GHG) emissions from food and farming whilst ensuring nutritious diets and a thriving sector will be key, and new research is needed to move the system in that direction. Equally important will be food and farming systems that are resilient and can withstand shocks and perturbations, for example from climate change and extreme weather, or pests and diseases.

In terms of the funding landscape, new funding mechanisms have been introduced such as the Global Challenges Research Fund, the Newton Fund and the Prosperity Fund, which will provide new opportunities to develop science and innovation partnerships that promote the economic development and welfare of developing countries, whilst also bringing benefits to the UK. A new National Productivity Investment Fund will add an extra £2 billion a year for research and development by the end of this Parliament. Part of this will support the Industrial Strategy Challenge Fund, a new interdisciplinary fund to support collaborations between business and the UK's science base, and GFS will help identify key food system challenges and coordinate input across funders. The establishment of UK Research and Innovation will also enhance the potential for interdisciplinary working to help solve grand challenges such as food security, and GFS will take a leading role in this area.

Interdisciplinary and whole system approaches to research on UK and global food supply systems are cornerstones of the GFS Programme. This includes the activities and outcomes that the system as a whole delivers, across agriculture, storage, processing and manufacture, through to distribution, retail and consumption. It considers how the different areas inter-relate, and avoids the possibility that a solution based on one disciplinary view leads to unintended consequences elsewhere.



GFS coordinates research supported by its partners across government departments and agencies, the devolved administrations, Research Councils and Innovate UK. It builds on the partners' existing activities, aiming to add value to their current and future investments, and complementing rather than replacing their individual strategies. It brings additional coherence by acting as a focus for joint activities and helping to ensure alignment of individual activities with shared goals. It provides a platform for working in partnership with a wide variety of stakeholders and users, both internationally and in the UK. It also provides knowledge and evidence for policy development (nationally, regionally and locally) to enable food producers and processors, retailers, consumers and civil society to respond to and manage the challenges facing the food system. The programme is informed by the Ministerial-led Agri-Food Technology Council and the Food Innovation Network to ensure research is policy relevant, meets industry needs and ultimately delivers impact. Examples of our activities to date can be found in our impact report¹.

The programme comprises three integrated interdisciplinary research themes:

1. Resilience – understanding and managing the risks to the food system from environmental, economic and social shocks, the interplay between these, and ways to improve resilience of the food system both now and in the future.

2. Sustainable production and supply – including water, energy, nutrients and other inputs; land use and soils, with a particular focus on the sustainable use of resources; improving efficiency and reducing waste; farming systems; food production from crops and livestock; the role of new technologies; food processing, quality, manufacture and distribution.

3. Nutrition, health and wellbeing – including food quality and safety throughout the supply chain, nutrition across the life course, healthy and sustainable diets, consumer behaviour, food choice and accessibility.

Building on these themes, we have identified a number of interdisciplinary research priorities that would benefit from a food systems approach. These include Paris-compliant healthy food systems; climatic shocks to the food system; behaviour change for adoption of a healthy and sustainable diet; sustainable management of natural resources in food production; urban food systems; the gut microbiome and its impact on health; and informing the post-EU referendum policy landscape in relation to food and farming.

Our vision is to integrate, coordinate and disseminate research that will be influential in supporting food security goals. We will raise the profile of the food security challenge and ensure it remains high on the political and business agenda, particularly in the context of the SDGs, Paris Climate Agreement and the changing political environment. We will provide thought leadership, horizon scan for emerging challenges, and facilitate new interdisciplinary research. We will synthesise and translate knowledge into policy and practice, maintaining our reputation as a credible and independent source of evidence and analysis. We will influence and build on individual partner strategies, taking holistic approaches to research on food systems. We will look both to the shorter term and the longer term, encourage innovation and provide a focus for UK contributions to wider international efforts.



¹ Impacts from the GFS Programme

2. Introduction

1. The UK's main public sector funders of food-related research and training are working together to coordinate research, innovation and associated activity on Global Food Security (GFS)². The GFS programme is intended to help meet the global challenge of providing the world's growing population with access to environmentally, economically and socially sustainable, safe, affordable and nutritious diets, which will need to be produced and supplied from the same or less land and with lower inputs of finite resources. GFS takes interdisciplinary and whole system approaches to research on food security. The aspiration is that by working together and developing a shared understanding of the challenges, and shared goals, we can have greater impact.

2. The political, scientific, and funding landscapes in which we operate are evolving. The UK has voted to leave the European Union which will have significant implications for UK food and farming policy. There will be an increasing need for evidence on how we might replace the Common Agricultural Policy to ensure positive outcomes for farming, the UK economy, health and the environment. Evidence will also be needed around how we maintain the UK's food security, including understanding the optimal balance between imports and exports, effects on the availability of different foods and public expectations around this, and new opportunities for trade and inward investment. In the context of a new regulatory environment, the role of new and existing technologies in helping to deliver sustainable intensification can be re-evaluated, on the basis of the latest evidence and a risk-based rather than hazard-based approach. The challenge around seasonal labour provides new opportunities for research on precision agriculture technologies, including automation, sensors and data.

3. The food security challenge is also evolving – globally there are now more people who are obese than underweight; the UN's Sustainable Development Goals (SDGs) have been published with a focus on sustainable production and consumption alongside ending poverty and hunger;³ and there was agreement at the Paris Climate Conference (COP21) to aim to limit global warming to 1.5°C and to keep it well below 2°C.⁴ Reducing GHG emissions from food and farming whilst ensuring nutritious diets and a thriving sector will be key, and new research is needed to move the system in that direction. Equally important will be food and farming systems that are resilient and can withstand shocks and perturbations, for example from climate change and extreme weather, or pests and diseases.

4. Meeting the challenges of our future food supply is not just an issue for government: it involves everyone across the food system. Therefore, the GFS programme will continue to provide knowledge and evidence to enable policymakers (national, regional and local), food producers and processors, retailers, consumers and civil society to respond to and manage the challenges facing the food system. Food security for the UK is inextricably linked to global production, demand and supply and must be considered in this broader context. GFS will continue to address these challenges and related global issues, including the many challenges confronting the developing world in the face of environmental and demographic change.

5. The programme is broad in scope: it integrates research in topics ranging from food production and processing to markets and distribution, consumption patterns, human nutrition, behaviour and all aspects of sustainability including environmental impact. A key aspect is adding value to current and future research and innovation through greater coordination, to improve the design, delivery and translation (into policy, regulation and practice) of research across many disciplines. Translation involves knowledge exchange and engagement with a broad range of stakeholders including agri-food and all other relevant industrial sectors.



² For a definition of food security, see paragraph 7

³ Sustainable Development Goals (SDGs)

⁴ Paris Agreement

3. VISION

6. Our vision is to integrate, coordinate and disseminate research that will be influential in supporting food security goals. We will raise the profile of the food security challenge and ensure it remains high on the political and business agenda, particularly in the context of the SDGs, Paris Climate Agreement and the changing political environment. We will provide thought leadership, horizon scan for emerging challenges, and facilitate new interdisciplinary research. We will synthesise and translate knowledge into policy and practice, maintaining our reputation as a credible and independent source of evidence and analysis. We will influence and build on individual partner strategies, taking holistic approaches to research on food systems. We will look both to the shorter term and the longer term, encourage innovation and provide a focus for UK contributions to wider international efforts.

4. CONTEXT

7. The United Nations Food and Agriculture Organization (FAO) has stated⁵: *“Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.”* Future generations are implicitly included in “all people at all times” and this requires food systems to be sustainable.

8. Globally, sufficient calories are produced to feed the current population, but access to a safe, sufficient and nutritious diet is unequal around the world. Around 795 million people globally do not have adequate food to meet their basic nutritional needs,⁶ and just under 2 billion people suffer from micronutrient deficiency,⁷ affecting their health and life expectancy. The estimated impact of undernutrition on gross domestic product (GDP) is 11% every year – more than the annual economic downturn caused by the global financial crisis.⁸

9. At the same time, just under 2 billion people are classified as overweight or obese, with increased risk of non-communicable diseases (NCDs) such as cardiovascular disease, stroke, certain cancers and type II diabetes. There are now more people who are overweight or obese than underweight in the world, with the two combined accounting for more than half of the world population.⁹ It has been estimated that 30,000 deaths per year in England and 5% of deaths globally are due to obesity and associated diet-related disease, costing the world economy an estimated \$2 trillion per year. In the UK, diet related chronic disease accounts for £5 billion of annual NHS spend and costs the wider economy more than £40 billion per year.¹⁰

10. As the global population grows from about 7.4 billion to more than 9 billion by mid-century, there is the potential for the food security crisis to deepen. The FAO has predicted that demand for food will grow by 38% by 2030 and 60% by 2050.¹¹ The food security challenge, in essence, is to meet the rising demand for food in ways that are environmentally, socially and economically sustainable, and in the face of evolving world-wide markets, global climate and demographic changes, and by so doing provide an acceptable, safe and nutritious diet for all.

11. In future, food supply (including production, processing and distribution) must – as far as possible – use the same or less land and fewer inputs, produce less waste and have a lower environmental impact.¹² Food must be safe, nutritious and affordable, and available to all, with improved equity of distribution, and reflect social and cultural needs. Pressure on production systems



5 Rome Declaration on World Food Security and World Food Summit Plan of Action. World Food Summit, Rome (FAO, 1996)

6 The State of Food Insecurity in the World (FAO, 2015)

7 Combating Micronutrient Deficiencies: Food-based Approaches (FAO, CAB)

8 Global Nutrition Report 2016: From Promise to Impact – Ending Malnutrition by 2030 (IFPRI, 2016)

9 Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19.2 million participants (The Lancet, 2016)

10 Overconsumption and Influences on Diet (GFS, 2016)

11 World Agriculture Towards 2030/50 (FAO, 2012)

12 This is the notion of sustainable intensification in Agriculture: Premises and Policies, Science Vol. 341 no. 6141 pp. 33-34 (Garrett et al 2013)

needs to be reduced by helping consumers to make better food choices for health and sustainability. There also needs to be a reduction in food waste across the system, and appropriate re-use of waste through the circular economy.

12. Food and soft drinks is the largest manufacturing sector in the UK and 4th largest in the world. The UK food supply chain represents 6.8% of gross value added (around £107bn) and 4 million jobs with around 500,000 people in farming and fishing and over 400,000 people in food manufacturing.¹³ Translating research into innovative technologies, practices and information could enable countries worldwide to meet existing and future food and environmental challenges while also contributing significantly to UK and global economic growth.

13. Significant parts of the knowledge and evidence developed within the GFS programme will feed directly into government strategies. The UK's departure from the EU will have significant implications for UK food and farming policy and also for UK food security; GFS will have a key role in providing the latest evidence, research and innovation to inform policy and practice in these areas.

14. A number of publications have provided analysis and insight on the Global Food Security challenge and have helped inform the drivers and challenges in the next section.¹⁴

Global food security drivers and challenges

15. Some of the main **drivers** underlying the challenge of ensuring food security for the UK and globally are summarised in the following points.

- + **Global population growth, demographic change, and increasing affluence and urbanisation**, will lead to growth in demand for food and changing patterns of demand – rising affluence is associated with increases in food consumption, especially of meat and dairy products. Much (but not all) of the expansion in population will occur in developing countries: improving food security (especially affordability and availability) is closely linked with the need to reduce poverty. Increasing demand for food from sub-Saharan Africa and Asia will also, via the globalised supply chain, create economic drivers for developed world agriculture.
- + **Global climate and other environmental changes** that will have direct or indirect impacts on food production, fisheries and supplies, including rising carbon dioxide and other greenhouse gases, leading to rising temperatures, changing rainfall patterns and increasing incidence of extreme weather events (such as storms, floods, heat waves and droughts), sea level rise and ocean acidification. Indirect changes include socio-economic responses to the physical changes in climate and adaptation or mitigation (e.g. changing crops or livestock systems). A changing climate may also lead to changes in the distribution and/or severity of pests and diseases in crops and animals and has the potential for severe impacts on food production and animal welfare. As well as threats, changes in climate may offer new opportunities for food production in some parts of the world.
- + **Environmental impacts** of farming, fishing, food processing and manufacture, storage, transport, retail, consumption and waste disposal: negative impacts can include increasing water and land use, soil erosion and degradation, loss of biodiversity, GHG emissions and water pollution. Food production is ultimately dependent on other ecosystem services so it is essential that these are maintained.

¹³ Food Statistics Pocketbook (2016)

¹⁴ Note: documents are cited as sources of useful background information and analysis. Some of the UK Government documents cited were published under the previous administration and do not necessarily reflect the current UK Government's policy position. The Bioeconomy to 2030 – Designing a policy agenda (2009); Agrimonde: Scenarios and Challenges for Feeding the World in 2050 (2009); Building our Industrial Strategy: green paper (2016); UK Cross-Government Food Research and Innovation Strategy (2010); UK Food Security Assessment (2010); Recipe for Success – Scotland's National Food and Drink Policy (2009); Focus on Food – A Partnership Strategy for the Food Industry in Northern Ireland (2010); Food for Wales, Food from Wales 2010-2020 (2010); The Neglected Crisis of Under-nutrition: DFID's strategy (2010); The Future of Food and Farming: Challenges and Choices for Global Sustainability (2011); The Green Food Project (2012); A UK Strategy for Agricultural Technologies (2013); A Pre-Competitive Vision for the UK's Food and Drinks Industries (2013); Feeding the Future (2013); A Cross-Council Vision for Food, Nutrition and Health Research (2015); The Role of Research in Global Food and Nutrition Security (2015); Sustainable Agriculture, Forestry and Fisheries in the Bioeconomy – 4th SCAR Foresight Exercise (2015); A Vision and high-level Strategy for UK Animal and Plant Health Research to 2020 and Beyond (2016); FSA Science, Evidence and Information Strategy 2015-20 (2015); UK Aid: Tackling Global Challenges in the National Interest (2015); DFID's Conceptual Framework on Agriculture (2015); Childhood Obesity: A Plan for Action (2016); Teagasc Technology Foresight 2035 (2016); Agrimonde-Terra: Foresight land-use and food security in 2050 (2016); Agrimonde-Terra: Foresight Land Use and Food Security in 2050 (2016)

- + **Key resources** for agriculture are limited, notably land, fresh water and energy, but also sources of other inputs such as mineral phosphate (an essential plant nutrient). Shortages of resources may be exacerbated by increasing competition, for example from urban and industrial development, and from food crops grown for other purposes such as bioenergy.
 - + **Social** drivers include urbanisation, demographic change, issues of land tenure, governance and international security, and changing patterns of consumer needs, preferences, habits and practices, affecting the demand for and consumption of different foods, and patterns of waste.
 - + **Economic** drivers include issues of trade, land tenure, trends in production and demand and potential for shocks, competitiveness of food and farming businesses and profitability, food markets and their volatility, supply and distribution, regulation, affordability and availability (particularly in the developing world) with associated globalisation.
 - + **Political** drivers include changes in government policy, new global agreements and political instability. The UN's Sustainable Development Goals (SDGs) have been published¹⁵ and there was agreement at the Paris Climate Conference (COP21) to aim to limit global warming to 1.5°C and to keep it well below 2°C.¹⁶ The UK leaving the EU will have significant implications for UK food and farming policy, and for UK food security.
 - + There is a need to ensure adequate and balanced nutrition, including not only calories but all necessary macro- and micro-nutrients for healthy diets and populations throughout the world.¹⁷ At the same time as increasing numbers of people globally are inadequately fed, over-consumption¹⁸ adds to the rising demand for food, with all the associated economic, social and environmental impacts. Overweight and obesity is on the rise with increased risks of cardiovascular disease, stroke, certain cancers and type II diabetes.
16. The GFS programme recognises the following important **challenges** arising from these drivers:
- + The world will need to produce more food and increase productivity, while using less land, water, fertiliser, energy and other inputs, and distribute that food more effectively, efficiently and equitably. On the demand side, manufacturing and retailing policies and patterns of consumption will need to change to improve health and sustainability.
 - + There is a need to reduce losses and waste, greenhouse gas emissions, pollution and other adverse environmental impacts throughout the food supply chain, from production to consumption, with appropriate re-use of waste through the circular economy.
 - + Food must be safe, nutritious and affordable, and be supplied and distributed in ways that meet the needs and aspirations of consumers in different economic, social and cultural contexts around the world.
 - + There is a need to balance different uses of land and seas, often with competing priorities. For example, sustainably increasing food production while maintaining other ecosystem services on which it depends and that are essential for society.¹⁹
 - + There is a need to understand and manage the risks from shocks to the food system and future volatility, as this can have adverse effects on consumers and producers, resulting in food price spikes and increased inequality and hunger as well as economic and political instability.

¹⁵ UN Sustainable Development Knowledge Platform

¹⁶ Paris Agreement

¹⁷ See also: The Neglected Crisis of Under-nutrition: Evidence for Action (DFID, 2009, revised 2012)

¹⁸ For example, see WHO information

¹⁹ See the UK National Ecosystem Assessment (2011)

- + There is a need to balance sustainable increases in productivity from food producing animals with their welfare, especially in the context of reductions in antibiotic use to combat antimicrobial resistance, recognising that preventative medication and high productivity do not always equate to high welfare standards and outcomes.
- + There is a need to support innovation and the translation of knowledge. In the UK, this would help companies grow and compete in a global market in areas such as agri-technologies and precision management, improved techniques in the supply chain and food preparation, and the production of safe and nutritious food of known provenance. Exporting this knowledge will transform the productivity of global agriculture, improving food security and opening up new markets.

17. The complex and inter-related challenges outlined above can only be tackled through coordinated and integrated interdisciplinary research and innovation, coupled with its effective translation into practice and policy. A main aim of the Global Food Security programme is to facilitate that research and its translation, and so help to improve the resilience, sustainability and security of UK and global food supplies.

18. The challenges range from those with a local, regional or UK national focus to more wide-ranging European and international issues. Food security for the UK is inextricably linked to global production, demand and supply and must be considered in this broader context. There is a key role for UK research (which is world-leading in various relevant fields) in helping to address the global challenges, especially those of developing countries. The benefits from such research often accrue to both developing and developed countries, for example through new research insights and opportunities, mobility of researchers and through exchange of technologies and know-how. With its recognised strength in world class science and interdisciplinary research, the UK is well placed to be the global partner of choice, creating opportunities and partnerships for innovation, exports and access to new markets; inward trade and investment; and overseas development.



5. The Global Food Security Programme

Operating principles

19. Mechanisms for working together through this programme include:

- + collaborative design and delivery of research;
- + cooperation in future strategy development so that funders' own programmes are aligned with shared goals;
- + joint horizon scanning activities, and sharing of knowledge, to identify and respond to emerging challenges and priorities;
- + collaboration on cross-cutting issues such as provision of training, skills and infrastructure for research, routes for translation of research, international partnerships, public engagement and dialogue;
- + joint engagement with key stakeholders, including through the Agri-Food Technology Council and Food Innovation Network²⁰.

20. As part of the process for enhancing coordination, the funding partners explore a range of mechanisms to bring together researchers with users for mutual benefit. Such mechanisms include interdisciplinary workshops to encourage academics and others with expertise in different research topics to work together, as well as building on existing relationships and networks as many of these are already established. In addition, such mechanisms promote interactions between researchers and relevant users of research, such as industry, government policy-makers and other stakeholders, in the UK and internationally. Benefits include improved communication among these groups and helping researchers gain greater awareness of the context in which their research is being used.

Partners and affiliates

21. The Global Food Security programme is jointly developed, designed and implemented by the UK's main public sector funders of food-related research and training. The partners and affiliates of the programme are:

- + Six of the UK Research Councils
 - Biotechnology and Biological Sciences Research Council
 - Economic and Social Research Council
 - Engineering and Physical Sciences Research Council
 - Medical Research Council
 - Natural Environment Research Council
 - Science and Technology Facilities Council
- + UK government departments, agencies and devolved administrations
 - Department for Business, Energy and Industrial Strategy
 - Department for Environment, Food and Rural Affairs
 - Department for International Development
 - Department for International Trade
 - Department of Health
 - Food Standards Agency
 - Foreign and Commonwealth Office
 - Government Office for Science
 - Innovate UK
 - Met Office
 - Scottish Government
 - Welsh Government
 - Wellcome Trust (observer)



²⁰ Food Innovation Network website

Added value of working together

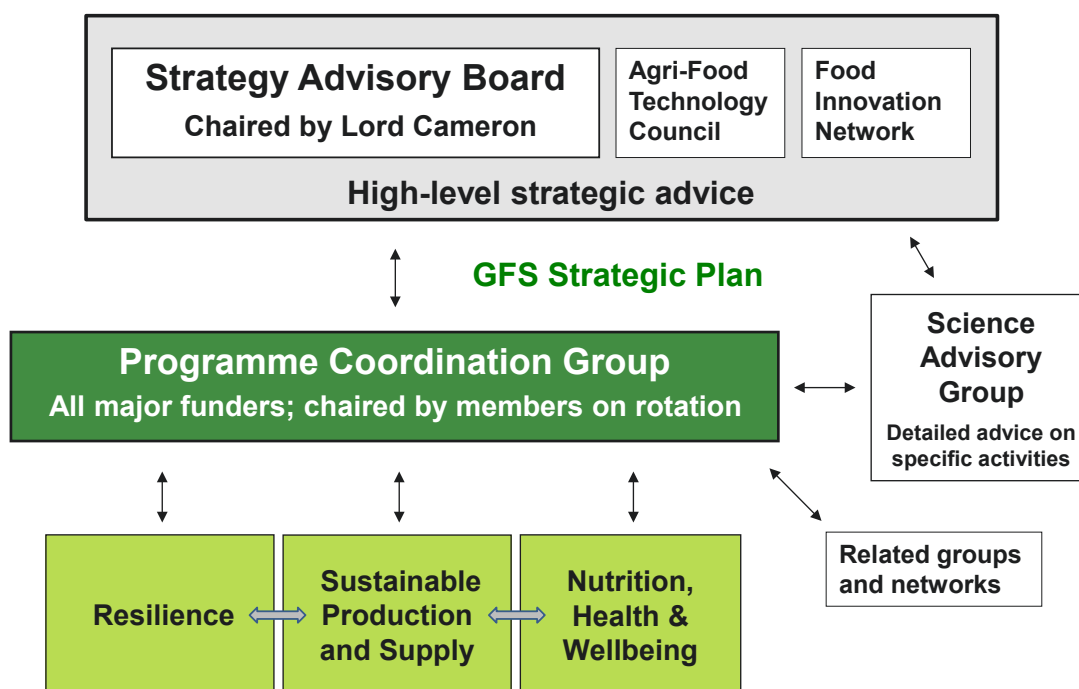
22. The funders recognise the increasing importance of food security as a major global challenge and aspire to maintain significant support for research within the constraints of the overall funding available to them. This programme is the result of that shared recognition and joint aspiration. The programme does not replace the partners' individual goals and priorities; rather, it aims to recognise and complement them and bring additional coherence by acting as a focus for joint activities and alignment of their individual activities with shared goals. A key aim is to maximise impact from available budgets and facilitate the sharing of information.

23. The programme provides added value through:

- + **Improved coordination and collaboration** between funders, end users and researchers, ensuring the major UK funders are more joined-up, with a single shared high-level strategy. This helps to focus research, innovation and training, and provide greater awareness of opportunities for co-funding, alignment and synergy, whilst avoiding duplication. It ensures greater efficiency and value for money, with partners working together to influence the funding landscape and achieve the best value from limited resources. It also ensures a more coordinated approach to knowledge exchange with key stakeholders.
- + **Increased innovation** through novel inter- and multidisciplinary approaches to address the challenges of delivering sustainable and competitive future food systems, and new products, processes and policy / regulatory approaches to support and encourage innovation.
- + **Greater leadership** by acting as a focal point for diverse research communities, industry, politicians, policy-makers and consumer groups. This helps to build a more integrated community of researchers and users (in the UK and overseas) and provides a platform to promote wider partnerships, including as a means to lever additional (non-UK exchequer) funding from the private sector and from international partner organisations. It also increases UK-international collaboration by offering a single port of call for partners who wish to engage with the major UK public funders and helps to ensure a more coherent UK approach to international food security activities.
- + **Horizon scanning and foresight** by providing a platform for partners to identify and respond to emerging priorities. This helps to maximise opportunities to work together on cutting-edge issues, and provides a means to address gaps in our knowledge by influencing the priorities of funding programmes such as the Global Challenges Research Fund (GCRF).
- + **Greater impact** through better coordinated dialogue and increased collaboration with wider stakeholders and users (such as the food and farming industry and related sectors, policy-makers, civil society and the public) for example working with the Agri-Food Technology Council and the Food Innovation Network on the translation and exploitation of research, and to ensure research has policy and industry relevance. The programme provides a mechanism to deliver key elements of relevant government and industry strategies.²¹ It helps to maximise the value and impact of food security research across government providing coherent evidence to support public policy imperatives, including through the GFS Food System Resilience Programme. It better links research priorities and outcomes to the development agenda, G8/G20 commitments and Sustainable Development Goals. It also ensures consideration of public views, aspirations and concerns around global food security so that research has the widest possible impact.

21 Such as The Future of Food and Farming: Challenges and choices for global sustainability (2011); A UK Strategy for Agricultural Technologies (2013); A Pre-Competitive Vision for the UK's Food and Drinks Industries (2013); Feeding the Future (2013); A Cross-Council Vision for Food, Nutrition and Health Research (2015); The Role of Research in Global Food and Nutrition Security (2015); A Vision and high-level Strategy for UK Animal and Plant Health Research to 2020 and Beyond (2016); FSA Science, Evidence and Information Strategy 2015-20 (2015); Childhood Obesity: A Plan for Action (2016); Building our Industrial Strategy: green paper (2016)

Programme governance and management



24. The overarching principles for the governance of the programme are that management arrangements should:

- + be simple and transparent;
- + be able to deliver added value from the partners working together;
- + provide clear lines of responsibility, accountability, decision making and reporting;
- + be inclusive and responsive to stakeholder/user needs;
- + allow the programme to be agile and action-orientated.

25. **A Programme Coordination Group** coordinates activities and maintains awareness of links with other relevant programmes. This group comprises the UK's main public funders of agri-food research and oversees the delivery of specific work packages developed under the programme to address key priorities, led by the GFS Secretariat. The group co-opts or draws on the advice of others to bring in additional scientific, stakeholder or other expertise as required. Related groups and networks feed into the programme via the programme partners and secretariat.

26. **A Strategy Advisory Board**, drawn from senior stakeholder representatives provides independent advice and guidance on the strategic direction of the programme and on technical issues. The Government Chief Scientific Adviser (GCSA) is a member of the Board. The programme is also informed by the Ministerial-led Agri-Food Technology Council and the Food Innovation Network to ensure collaboration and coordination, and to ensure research is policy relevant and meets industry needs. The programme engages wherever appropriate with key stakeholders (both national and international, and including NGOs).

27. **A Science Advisory Group** provides detailed advice on specific activities, as well as providing a challenge and horizon-scanning function to ensure the programme is working on the most cutting-edge activities. The group operates virtually but is brought together on an ad-hoc basis for horizon-scanning activities.

Delivering impact

28. This section sets out some overall aims and mechanisms for delivering beneficial impacts from the programme.

29. The programme aims to promote and facilitate integrated problem-based research, through encouraging the research community to proactively develop interdisciplinary collaborations and to seek new partnerships that will bring different perspectives and novel approaches. The funders aim to minimise any potential barriers to supporting such cross-cutting research.

30. Researchers are encouraged from the outset to consider the potential impact of their research. For example, the Research Councils require research proposals to include statements on 'pathways to impact', setting out what the researchers will do to explore and take forward the wider impact of their research. Research commissioned by UK government departments is inherently closer to impact since it is intended to address questions from users. DFID encourage all new projects/initiatives to engage users from the outset. The Scottish Government's strategic research portfolio is directed by end-user evidence needs. An overall aim of the Global Food Security programme is to improve the interactions and communication between the research community and users and policy makers.

31. **Knowledge exchange, innovation and translation:** The translation of research outputs into practical use and application by consumers, the agriculture and food industries, policy-makers and non-governmental organisations is critically important in meeting the future challenges. The programme partners work closely with users of research to encourage effective two-way knowledge exchange with researchers and so promote rapid and efficient translation into practice, thereby helping to deliver maximum impact from that research. One important component of this involves working in partnership with the Agri-Food Technology Council to help deliver the UK government's Strategy for Agricultural Technologies. The funders have in place a range of schemes to promote knowledge exchange and to engage with industry, policy-makers and other stakeholders (including links with representative bodies such as the relevant Knowledge Transfer Networks and the Agriculture and Horticulture Development Board). The Global Food Security programme builds on existing mechanisms but additional activity is needed and the programme actively explores new mechanisms to encourage such interactions. These may include new ways to build effective partnerships with commercial sectors, with consumers through novel public engagement, and with the diverse range of organisations working in the developing world and elsewhere internationally.

32. Meeting the challenges related to global food security means drawing on knowledge and innovations in a wide variety of research disciplines including animal and plant sciences, agricultural science, environmental science, food science, chemical engineering, process engineering, mathematics, electronics and a very broad spectrum of social science disciplines including economics, sociology, psychology, development studies and social policy.

33. This programme aims to draw on expertise across the entire food supply chain, encompassing businesses in agriculture, aquaculture and fisheries, food processing and packing, distribution and logistics, and food retailing. There is significant business strength in these sectors throughout the developed world with many organisations having a global presence, so innovative technological solutions form an integral part of the strategy with a view to exploiting them on a worldwide basis.

34. A key issue for the agricultural and food sector is accessing the right information to drive their businesses forward competitively and sustainably. The Food Innovation Network will join up the agri-food innovation landscape to provide a 'one stop shop' for innovation, and will give SMEs greater access to world-leading science and technology to innovate and grow. In addition, Innovate UK is a key partner in the programme and all of the partners work closely with them to build on mechanisms already in place to promote interactions with a range of commercial sectors and to facilitate innovation and translation. The programme provides a means for exploring potential new public-private partnerships.

35. As an example of a collaborative approach to research, the £14.5M GFS programme on Resilience of the UK Food System in a Global Context was co-designed by GFS partners with input from academia, the food industry and NGOs. The programme strongly encouraged collaboration with end users throughout the research process and we will aim to build on this mechanism in future.²²

36. **Skills:** Addressing the interdisciplinary challenges posed by food security requires a range of high-level skills, in terms of research itself and its up-take by users. An integral part of the programme is to ensure that public sector funders work together to support partnership across the wide range of bodies involved in addressing skills needs, such as universities and higher education colleges, agricultural colleges, research institutes, business and professional / trade bodies.²³ Skills are an integral part of the UK government's Strategy for Agricultural Technologies and future needs are being considered by the Agri-Food Technology Council.

37. One example of the provision of high-level skills is Innovative Food Systems Teaching and Learning (IFSTAL), which has been designed to improve post-graduate knowledge and understanding of the food system. Funded by HEFCE and encompassing five leading higher education institutions, IFSTAL complements postgraduate student training by offering skills in applying systems thinking to food security challenges. IFSTAL aims to ensure a new generation of food system practitioners, policymakers and researchers equipped to address food system challenges, by combining a deep understanding of their specialism with critical and innovative thinking of the broader social, economic and environmental contexts.

38. **Infrastructure for research:** The UK has world-class facilities and resources which underpin food security research, and which bring benefits not only to the UK but also internationally. Major facilities and centres of expertise at Research Council, government and devolved administration sponsored institutes, and within universities and the private sector,²⁴ form key parts of the national capability. The UK's agri-food research infrastructure is critical to enabling a longer term approach to the sector's needs in terms of research, knowledge exchange, training and facilities. The funders aim to adopt a strategic approach to coordinate support for research facilities and resources, including cooperation with counterpart organisations in other countries as appropriate, to ensure critical science resources and capabilities are not lost in any future changes.

39. **International:** Food security requires international collaborations and global responses. With its recognised strength in world class science, innovation and interdisciplinary research, the UK is well placed to be the global partner of choice. This will create new opportunities for international trade and enable inward investment through collaborative, interdisciplinary research and development. Interactions at various levels are important, including among researchers but also among research funding bodies. The UK funders cooperate with appropriate counterpart organisations in other countries and international programmes, building on the many interactions that already exist.

40. The UK has many international partnerships across the world, for example:

- + GFS provides secretariat support to the Sustainable International Temperate Agriculture Network²⁵. This network aims to increase international collaboration and coordination on sustainable temperate agriculture, and synthesise knowledge to inform global policy and practice.
- + The Global Research Alliance on Agricultural Greenhouse Gases²⁶ has been established to help reduce the emissions intensity of agricultural production. The UK membership of the Alliance is led by Defra, and opportunities will be sought to add value to activities within GFS through this international initiative.
- + Strong links exist between the UK and Brazil, and particularly Embrapa, the leading Brazilian agricultural research organisation, which has major domestic and developing world research programmes and a strong translation capability that is complementary to UK research strengths.

22 Announcement of GFS Food System Resilience Grants Call 1

23 One model is the Advanced Training Partnerships scheme, which brought together consortia of organisations with the aim of addressing the high-level skills needs of individuals employed in the food sector. A review of vulnerable skills and capabilities was recently undertaken by BBSRC and MRC and included many relevant to food security.

24 BBSRC and HEFCE study of land-based facilities and resources

25 Sustainable International Temperate Agriculture Network website

26 Global Research Alliance on Agricultural Greenhouse Gases website

- + The UK continues to work with China via the Sustainable Agriculture Innovation Network. UK and Chinese scientists have launched a new joint virtual centre to investigate and tackle the problem of nitrogen use in Chinese agriculture.
- + A new UK-India collaboration on aquaculture for food security, development and poverty reduction.



41. Developing countries face many of the most serious food security challenges. DFID is a key partner in the programme, and activities take account of the needs of the developing world for sustainable, safe, affordable and healthier food supplies. Investment in agricultural research is essential if we are to meet the Sustainable Development Goals (SDGs). Poverty and hunger are intimately linked and a significant proportion of the world's poor will continue to depend on agriculture for their livelihoods. Continuing to increase agricultural productivity – and doing so sustainably – will be essential. Globally we need to scale up agricultural research in order to tackle animal and plant health and productivity, and the overarching food security challenges of the developing world: rising food prices, climate and other environmental change and drastically changing patterns of food consumption, all of which exacerbate problems of hunger and poverty. The UK is a founding member and among the leading donors of the Consultative Group on International Agricultural Research (CGIAR), a global organisation that aims to harmonise funding to enable greater research focus on priority issues of climate change, poverty, food security and nutrition. Through new mechanisms such as the Global Challenges Research Fund, the Newton Fund and the Prosperity Fund there are new opportunities to develop science and innovation partnerships that promote the economic development and welfare of developing countries whilst also bringing benefits to the UK.

42. Collaboration with European countries, mobility of researchers, and access to EU research programmes will be essential to help meet the food security challenge. The UK government has agreed to underwrite awards to UK institutions from European Commission programmes such as Horizon 2020 that are made whilst the UK is still part of the EU.²⁷ The exact nature of the UK's relationship with the EU will be subject to negotiations but it is anticipated that research collaboration with European countries will continue, given the success of schemes such as the Joint Programming Initiatives on 'Agriculture, Food Security and Climate Change' (FACCE-JPI)²⁸ and 'A Healthy Diet For A Healthy Life', as well as ERA-nets such as ERA-Net SUSFOOD looking at sustainable food systems, the relationship between sustainability and food quality, consumer behaviour, and competitiveness. It will be important to continue to develop shared research agendas and to explore options for implementation.

43. **Communicating** the work and outputs of the programme is vital for the success of GFS. We will continue to position GFS as an authoritative voice on food security, and specifically food security research issues in the media. We will maintain and promote a website²⁹ which engages food security stakeholders and researchers in the issues around food security and on the activities of the programme. The influential and far reaching blog will continue to be a mainstay of GFS communication activity supported by other social media such as Twitter.³⁰

44. **Public engagement** and dialogue are an integral part of the programme. Food security raises many different and often inter-connected issues that are of high public interest in the UK and internationally, not least because it centres on that most emotive of issues: the food we eat. Over the last five years GFS has led the way in engaging the public and other stakeholder voices in discussions about the future focus and direction of food security

²⁷ See UK government press release

²⁸ FACCE-JPI website

²⁹ GFS website

³⁰ @FoodSecurityUK Twitter page

research. This will continue to be important, especially in the context of a changing political environment, and the need to understand a diverse range of views on the UK's future food and farming policy.

45. The programme has adopted best practice methods to engage a wide range of stakeholder opinion on the issues. Engagement and dialogue with the public, including representative groups and NGOs, ensures that researchers can consider public aspirations, concerns and attitudes as they shape the scope and direction of their projects. This is essential for building trust and confidence in the work of researchers and ensuring that all interested parties have a voice and are listened to, as well as helping to indicate important factors in the application of the research outputs.

46. The GFS programme recently conducted a series of public dialogues on a wide range of food security issues through the Food Futures Public Panel³¹. We will maintain our commitment to developing our strategy and activities with the participation of a wide range of viewpoints and perspectives from stakeholders and the public.

Monitoring progress

47. Progress within the programme is monitored and reported regularly, for example through publications and dissemination events as appropriate.

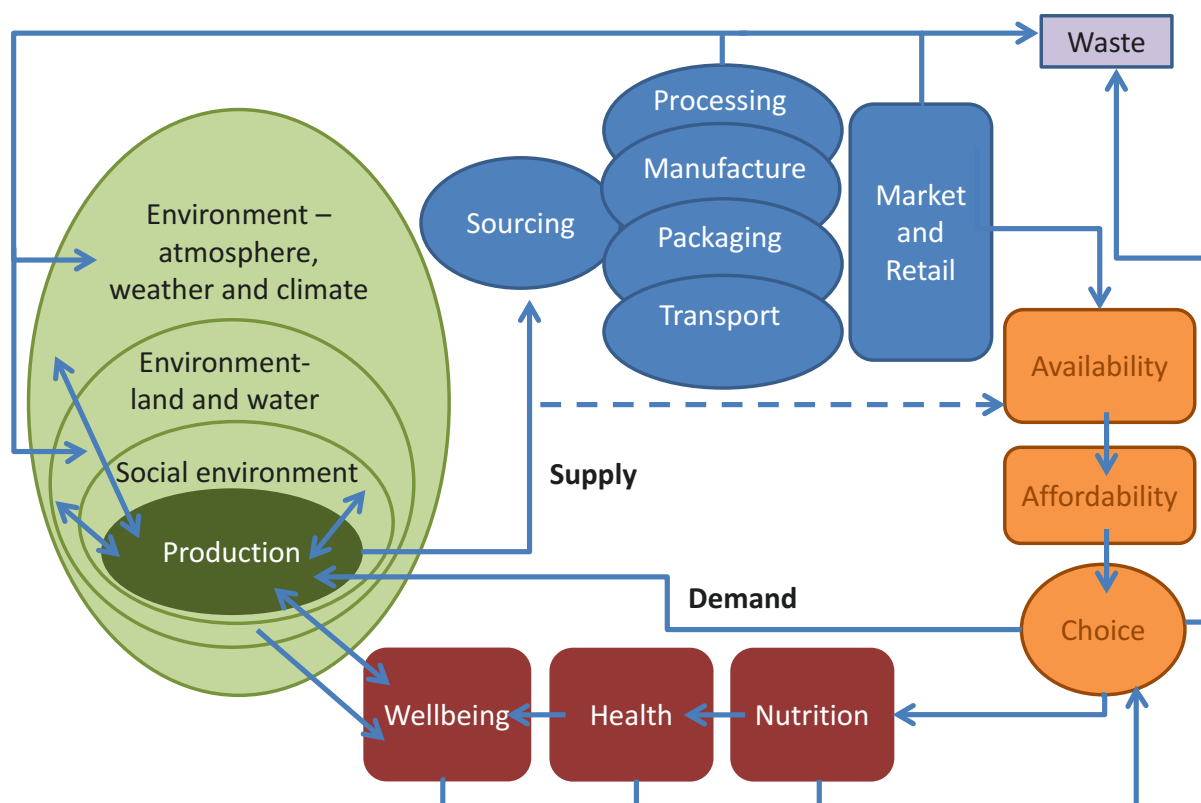
48. The funding partners keep the operation of the programme (and its various mechanisms for joint working) under regular review, making adjustments and instigating modified arrangements as necessary. The Strategy Advisory Board has a key role in maintaining an overview of the programme.

³¹ Food Futures Panel outputs

6. RESEARCH THEMES

49. Food security arises from a well-functioning, resilient food system and its activities and outcomes. The food system is highly interconnected and operates across a range of spatial and temporal scales. The interests of GFS partners and stakeholders span the whole food system. For example, food choice has a direct impact on primary producers (and their interactions with the environment), food manufacturers, processors and retailers, and on all aspects of sustainability and trade, and cannot be considered in isolation. A food system perspective helps to identify the many biophysical, social and economic interactions across a range of drivers and scales that determine food security.

Figure 1. An indicative representation of the food system

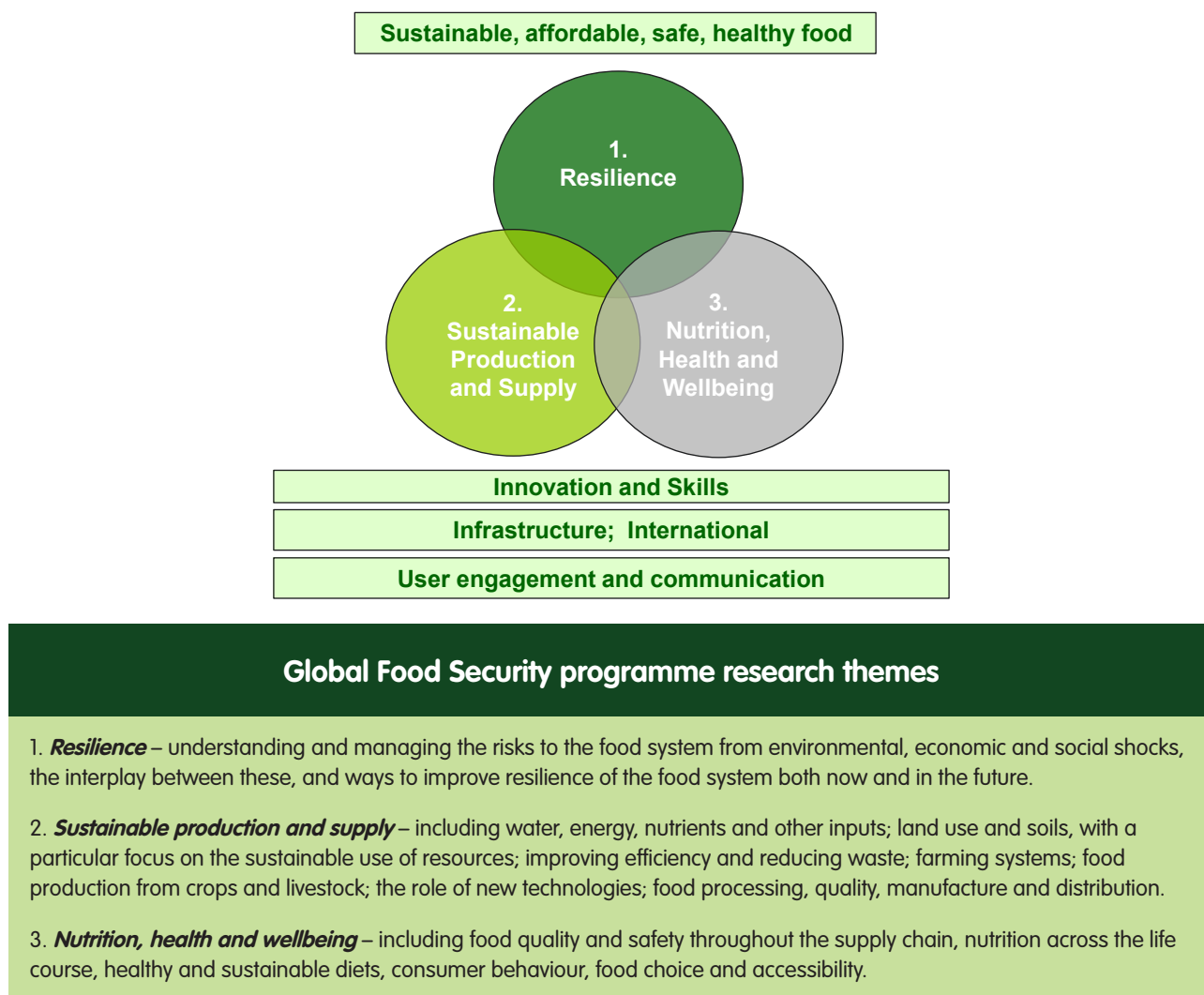


50. Research in the programme will be coordinated in themes set in the wider context of the food system. The themes are deliberately interdisciplinary, bringing together complementary research approaches, and cutting across the remits of the funding partners.

51. All of the themes are inter-related and synergistic (as summarised in Figure 2). All themes will address cross-cutting issues such as: innovation and the translation of research; the provision of skills; infrastructure for research; international collaboration and cooperation; and user engagement and communication.

52. The themes describe the breadth of research being supported by partners in the programme and provide a framework for coordinating, influencing and shaping these activities, as well as aligning research agendas to address emerging challenges. This section sets the wider context for the priorities highlighted in section 7, which specifically identify key areas where the GFS programme can add value through interdisciplinary, food system approaches.

Figure 2. Global Food Security programme research themes.



Theme 1. Resilience

53. As the world becomes more interconnected, the climate increasingly variable and the competition for resources increases, a range of complex risks will exacerbate the shocks and challenges faced by communities.

54. The notion of resilience encompasses the way that a system responds to shocks: in terms of whether a shock causes a system response, the magnitude and return time of the response to the original state, and the potential for moving to another state entirely. Sustainability is strongly linked to resilience: systems that are resilient are likely to be able to function or adapt under perturbations and thus be sustainable.

55. Shocks to the food system often affect the poor in developing countries the most as they are the least resilient to changes in food prices and availability, with limited economic capacity and infrastructure investment to underpin recovery. Developing countries have historically suffered (and still suffer) the worst effects of food system shocks and these are frequently felt in the form of food poverty, hunger and starvation.

56. An efficient and equitable food system that meets the needs of all people in a sustainable way is dependent upon fit-for-purpose markets, regulatory frameworks and supply chains that are flexible and have the capacity to respond to and absorb shocks. Research under this theme will understand the causes and impacts of shocks to the global food system and identify ways of building resilience at all levels, from local subsistence producers to global markets. This will help strengthen the capacities of people and communities to adapt to changing circumstances, manage an increasingly complex risk environment, and cope with shocks they are unable to prevent.

57. For resilience to be achieved, consideration must be given to biological, economic, environmental, and social factors and the interplay between these at local-to-global levels. Factors might include competitiveness and sustainability of food and farming businesses, regulation of new and existing technologies, climate change and extreme weather, new pests and diseases, natural hazards and disasters, international trade, food markets and food price volatility, domestic policies in a globalised food system, food availability, political instability, and food safety issues. Research will need to take an integrative and interdisciplinary approach to identify the trade-offs that exist in relation to these factors; for example, the use of export bans in developed countries as a resilience measure can have a detrimental effect on the poor through disproportionate increases in food prices.

58. The leading economic models of agricultural markets used by international organisations such as the OECD-FAO are not always sensitive to analysing short-term price shocks. Given that such fluctuations often push the world's poorest people into hunger, further research is needed to better understand within-year price volatility, its drivers, mitigation and impact on the food insecure.

59. Research will help provide solutions to enhance trade and develop our understanding of access to reliable markets, particularly for those in developing countries. This will emphasise the role of infrastructure (and other public goods), governance, trade and broader economic development that contribute to food security in low-income countries over the medium term.

60. Further research is needed on resilience to extreme weather events, including the potential for better forecasting and the interaction between weather, farm management, logistics and resilience at multiple scales from field to globe, with multiple timescales. Extreme weather has an immediate impact on food production and transport, directly affecting livelihoods and health through changes in accessibility and affordability, and this has been linked to political instability.³² Wider environmental resilience is equally important in soil, water supply, nutrients, and land use and there is a strong link to theme 2.

61. Over the longer term, it is imperative to improve understanding of the complex interactions between the changing global climate and agriculture (including land use), the supply chain and markets in order to improve adaptation and resilience. The frequency and intensity of some disasters such as persistent droughts, floods and storms could increase, with an adverse impact on livelihoods and food security. In this context it will be important to strengthen the evidence-base on the most effective approaches to building national and local resilience for better disaster risk management in the context of food security, building on DFID's programme on Disaster Risk Reduction.

62. An improved understanding is also needed on contemporary food supply chains in terms of their resilience, risks and security. This includes the potential for system dysfunction, along the continuum from normal operation to failure (including to the extremes of food fraud) with specific focus on the implications for food safety and authenticity, consumer trust and food security.



Theme 1. Resilience

Example research areas

- + Improving understanding of the critical factors affecting the resilience of households, world trade and global food supply and the role of economic, social and environmental factors.
- + Developing and enhancing economic models of trade flows, agriculture and hunger that capture the impacts of within-year shocks.
- + Sector wide resilience to climate change (including extreme weather events, emerging pests and diseases, changes in biodiversity and ecosystem services provision) - with improved competitiveness, environmental performance and positive social outcomes.
- + Developing evidence to inform policy recommendations around improvements in infrastructure (and other public goods), governance and broad economic development that contribute to food security.
- + Developing a better understanding of the effects of existing systems, markets and regulatory frameworks with a view to enhancing their effectiveness, in particular in relation to managing unexpected shocks and perturbations.
- + Developing insights that inform how policy might underpin risk management strategies to help build resilience for producers and suppliers in the developing world.

Theme 2. Sustainable Production and Supply

63. Theme 2 covers sustainability in relation to all aspects of food production, including farming systems and production from crops and livestock (including farmed fish), food processing, manufacture and distribution. It includes water, land, energy, nutrients and other inputs, and the sustainable use of resources; increasing competitiveness, profitability and efficiency; and reducing waste and pollution. Integrated and whole systems-based approaches to research will be essential.

64. A sustainable food supply system depends critically on maintaining ecosystem services and preserving biodiversity. These help ensure healthy soils that can provide essential nutrients, a sufficient and clean water supply, pollination services and good air quality. It is imperative that the food system delivers such essential services and resources alongside the production of food.

65. Sustainable intensification (SI) is a necessary condition for growing more food from the same footprint of land. Four underlying premises³³ have been described: (i) the need to increase production of nutritious, safe food in an environmentally sustainable way; (ii) increased production must be met through higher yields because increasing the area of land in agriculture carries major environmental costs; (iii) food security requires as much attention to increasing environmental sustainability as to raising productivity (SI does not mean business-as-usual food production moderated by marginal improvements in sustainability); iv) SI denotes a goal but does not specify a priori how it should be attained or which agricultural techniques to deploy. SI has to be placed in the context of land use and global trade, with each country ideally producing food that is best suited to its local environment and trading the excess.

66. Resource efficiency can be achieved through the delivery of competitively priced goods and services that satisfy demands and bring quality of life, while progressively reducing ecological impacts and resource use intensity throughout the life-cycle to a level at least in line with the Earth's estimated carrying capacity. Key aspects include measures on output per unit input, waste, energy consumption (including renewable energy usage), water consumption and greenhouse gas emissions, as well as external costs (environmental, social and economic) of food transport and food imports.

33 Sustainable Intensification in Agriculture: Premises and Policies, Science Vol. 341 no. 6141 pp. 33-34 (Garrett et al, 2013)

Theme 2. Sustainable Production and Supply

Example research areas

- + Enhancing production and productivity of crops, farmed animals and fish while minimising losses and adverse environmental and social impacts, maintaining high standards of animal welfare and maintaining essential ecosystem services. In particular:
 - increasing and maintaining resilience of yields, through modern breeding technologies, better crop management and maintaining healthy and productive soils.
 - reducing greenhouse gas emissions from the food and farming sector including in ruminant livestock through enhanced understanding of their biological processes, and more efficient use of energy, manures and fertilisers through improved management practices.
 - developing more sustainable approaches to fish farming, including sustainable sources of fish feed and management of pests and diseases.
 - minimising prevalence and impact of pest and diseases through prevention, improved detection and controls and safety (e.g. biosecurity).
 - combatting resistance in pest, pathogens and weeds, informing and responding to regulatory change (e.g. in pesticide use) and protecting crops through Integrated Pest Management.
- + Understanding agri-food systems at a landscape & catchments scale and improving understanding of the interaction between the agricultural system and the wider environment.
- + Optimising the use of resources (e.g., water, land, energy, nutrients and other inputs) while increasing crop and animal productivity (per unit input), improving precision and use of novel technologies throughout the supply chain, and reducing / re-using waste.
- + Greater use of big data, open data, informatics, internet of things, and modelling to support decision making on farm and within food businesses (for example 'Agriculture 4.0' and the integration of precision agriculture, robotics and digital technology). This includes new technological developments from other sectors that might be used in the food system, for example block chain technology for improving food chain transparency.
- + Breeding crops and animals for enhanced quality e.g. nutrient composition to meet consumer needs.
- + Reformulation - understanding how fat, sugar, preservative and salt content of foods could be reduced while maintaining palatability and safety, minimising waste, and improving the sustainability and quality of raw materials.
- + Developing new food processing and manufacturing technologies to reduce energy use, maintain nutritional quality, enhance shelf life, prevent post-harvest spoilage and reduce waste.
- + Improving understanding of the attitudes, habits and practices that affect current patterns of food production and supply (including resource use and associated waste) in the food system, with a view to embedding more sustainable practices in the short and long term and resilience to climate and other environmental change.

67. Research is needed to achieve sustainable increases in overall production and productivity of crops and farmed animals. This will include research to tackle long-term challenges with the potential to offer a step-change in both crop and livestock production. In crops, examples could include improving the efficiency of photosynthesis or other long-term approaches to the sustainable intensification of crop production. There is also the potential for major improvements in the efficiency with which crops use water and other resources or exploring the possibilities for nitrogen fixation in cereals.

68. Much can be done to increase crop productivity and production in the shorter term (in both high and low income countries) by closing the yield gap, raising actual yields towards the full potential yields that should be achievable under the prevailing conditions whilst maintaining or improving quality (for example, as achieved on demonstration farms). Sustainable approaches could include improved crop rotations and improving soil management.



69. Research will be needed on more efficient use of water and nutrients and on quantifying and reducing greenhouse gas emissions and waste throughout the food chain. This includes increasing soil availability of water and nutrients to crop plants while minimising inputs, through for example modified agronomic practices and reducing water waste. In addition, research should explore ways to enhance carbon storage, especially in impoverished soils. Approaches could include modified farming practices, optimised management of crop residues and soils, increased plant root and other biomass in soils, and application of exogenous organic resources such as composts, sludges and pyrolised material (Biochar).

70. There is also a need for research to reduce diffuse water pollution, including characterising the relative contributions of different sources and understanding catchment processes controlling pollutant transport and attenuation. In the UK, the Defra-funded Demonstration Test Catchments provide a platform to host long-term research on pollutant mobilisation, transport, impact and mitigation at field to catchment scales. The sustainable use of water by agriculture (including the environmental impact of water abstraction) and the role of embedded water in relation to global water security are also important areas.

71. For livestock, examples of research approaches may include increasing energy and protein conversion efficiency, improving herd health and reproductive efficiency, lowering maintenance requirements, as well as closed loop management systems. Reducing greenhouse gas emissions from ruminant livestock is an important priority and includes studies of animal nutrition and gut biology. Increased demand for animal-derived food products is likely to drive more farmers to employ more intensive farming methods. The specific welfare requirements of animals in new production systems need to be taken into account to ensure a sustainable food supply without compromising welfare standards, food safety, nutritional quality, or increasing disease risks and anti-microbial resistance.

72. Aquaculture is of increasing importance to food supplies globally, but there is a need to develop more sustainable approaches to aquaculture, including sustainable fish feed (to reduce dependence of aquaculture on wild-caught fish), management of fish diseases and pests (notably sea lice) and management of environmental impacts. Approaches could include sustainable exploitation of other marine sources such as algae, production of plant-derived fish feeds that provide necessary nutrients, and integrating aquaculture activities with land-based farms.

73. Research is needed to improve energy efficiency and reduce energy use and associated greenhouse gas emissions throughout the food system, notably in food production, processing, refrigeration, transport, retail and storage, as well as through waste minimisation and utilisation. This includes flexible manufacturing, energy and water saving / re-use systems, and new technologies and management systems to reduce energy and water consumption.

74. Losses need to be reduced throughout the food system. Research to reduce losses in food production from crops and farmed animals should aim to enhance resistance and improve prevention and management of pests and diseases (including exotic and endemic animal infectious diseases, many of which are zoonoses that can transfer to humans, and mycotoxins that impact on food safety). Research on pest, disease and weed control for better crop protection would include integrated pest management and other approaches to reduce inputs of pesticides, as well as studies to understand more fully and mitigate the impacts of pesticide use on ecosystems associated with agriculture. Approaches such as intercropping can show marked benefits for pest control. Importantly, and linking to theme 1, research should also aim to enhance tolerance to abiotic stresses such as drought, flooding or high temperatures, in the context of a changing climate.

75. Reducing waste in the production, transport, storage, retailing and consumption of food, and the recovery of resources or re-use of waste through the circular economy, would bring multiple benefits including increased food availability, reduced use of inputs (including energy), reduced greenhouse gas emissions (arising directly from waste food going to landfill and indirectly from all stages of the supply chain) and financial benefits to producers, retailers and consumers. Innovative ways are needed to reduce the very large extent of waste in the food system, and to ensure that improvements are implemented in practice at all stages of the supply chain. This can be achieved through innovation in crop breeding (such as for improved shelf life) and post-harvest technology (such as information and communication technologies, robotics and non-invasive sensors) to reduce storage losses and waste and maximise yield and quality, as well as through social innovation across the food chain. Innovation in intelligent/smart packaging technology can also reduce spoilage and extend shelf life, including in the home.

76. Management of agricultural systems can be improved through the development of decision-support and management systems at a range of scales (farm, catchment, regional) to optimise food production in ways that are reconciled with the delivery of other critical ecosystem services and maintaining biodiversity. Improvements can also be made in logistics and management systems for food transport, storage, distribution and retailing.

77. Research is needed to improve our understanding of how markets and social drivers (for example consumer demand) affect food producers' methods and technologies, with the aim of developing interventions that will embed production and process innovation practices that are more economically, environmentally and socially sustainable in the short and long term. This includes the relationship between food production and nutrition, with research to enhance the quality of meat, dairy and crops, and explore the potential for biofortification and reformulation in food manufacturing (there is a strong link to theme 3).

Theme 3. Nutrition, Health and Wellbeing

78. Theme 3 includes food quality and safety throughout the supply chain, and diet, nutrition, health, and wellbeing across the life course, as determined by accessibility, consumer behaviour, food choice, cultural and social practice.

79. Ideally, food should be produced, processed, distributed, retailed and consumed in a society where people can access a safe, healthy diet and are able to make informed choices about what they eat, the origins of their food, its nutritional quality and sustainability. A reliable, safe food supply, which is accessible and affordable, needs to be developed, maintained and secured, with consumers having confidence in the safety and quality of the food available to them.

80. The interconnectedness of global food systems and value chains, economies and environments is increasingly evident and food system policies made in one world region will have impacts on economic, health and environmental outcomes in other parts of the world. The shifts in national and regional dietary patterns resulting from factors such as economic development, health seeking behaviours, concerns for the environment, and resource scarcity can lead to complex interactions. The double burden of hunger and undernutrition, and overweight and obesity, needs to be tackled urgently, given that one in three people across the globe now suffer from some form of malnutrition.

81. This theme will help develop an improved understanding of the link between dietary health, sustainable food production and consumer behaviour, to improve population-level nutrition outcomes and the environmental, social and economic sustainability of habitual diets globally. Further research is needed on what constitutes an acceptable, nutritious, healthy and sustainable diet and how this differs across the globe; how factors such



as equity, preference, habit and social practice shape diets of different populations; the short and long-term implications of dietary practices on health across the life course, and the interplay with other lifestyle factors.

82. A better understanding is needed on the drivers of food choice, the scope for positive interventions to improve diets and the role of different actors across the food supply chain in both developed and developing countries. The nutrition transition that often occurs during economic development and leads to a shift in consumption patterns towards diets that contain more sugar, salt and fat is associated with the rapidly rising incidence of obesity and associated non-communicable diseases. Understanding the drivers of food and nutrition security including food availability, supply, affordability, utilisation and food choice, and the scope for positive agriculture and food system interventions for health is critical.

83. The development of healthy food products, including via fortification or reformulation, could also have a positive effect on nutrition outcomes and benefits for health. Further research is needed on novel and functional foods and consumer acceptability.

84. To provide safe and nutritious food for a growing world population, it is important to reduce the incidence of food poisoning. This requires a better understanding of how novel, emerging and re-emerging pathogens can be prevented, detected and controlled rapidly to enhance food security. Traceability and analytical tools to verify the origin and composition of foods, and where and how they have been produced, will ensure consumers are confident about where their food comes from and trust that it is safe.

85. Research under this theme will be responsive to changes in other parts of the food system. For example, if research generates a new high-yielding crop, the effects of its incorporation into the diet on health will need to be assessed. Likewise, its introduction may have effects on food safety (is it resistant or sensitive to fungal contamination, does it introduce new allergenic potential?) and on wider aspects of sustainability of the diet. In addition, issues around food price and food supply may give rise to concerns about increased drivers for food fraud with potential impacts on food safety, which may require further investigation.

86. A major objective of this theme is to ensure that, when changes in the food system are made in response to a range of drivers, the effects of those changes on safety and health within a sustainable food system are not neglected.

87. Major programmes of research³⁴ are in place outside Global Food Security to address topics such as the role of diet and lifestyle in health and the development of disease, food safety and sustainability. It is anticipated that research in these related programmes will be valuable in informing developments in this theme and the Global Food Security programme more widely.

³⁴ Examples include:
MRC Metabolic Diseases Unit and MRC Epidemiology Unit, Cambridge and MRC Gambia Unit
International Nutrition Group
The Quadram Institute, Norwich, MRC/CSO Social and Public Health Sciences Unit, Glasgow
Scottish Government healthy safe diets research
FSA food-borne illness research and chemical contaminants research
Diet and Health Research Industry Club (DRINC)



Theme 3. Nutrition, Health and Wellbeing

Example research areas

- + Developing a better understanding of a healthy, sustainable and safe diet and how this can be achieved in the context of variable consumer access and availability of food stuffs.
- + Nutrition and malnutrition – including improved understanding of how foods interact with the body; the role of the gut microbiome; micronutrient requirements; and the differing nutritional needs of various groups who are subject to the challenges posed by food security-related issues.
- + Improved safety, traceability and integrity across the food chain – e.g. on-farm tests, smarter packaging, reduction in harmful microorganisms and toxins, 'fit for purpose' detection methods for verifying food safety, food quality and composition.
- + Microbial and chemical food safety and food intolerance – including reducing the incidence of key food-borne pathogens throughout the food supply chain; identifying and addressing emerging and re-emerging food safety risks.
- + Responsible innovation³⁵ and the challenges and opportunities (technological, social and economic) arising from the proposed application of emerging technologies.
- + Packaging engineering to reduce retail and consumer waste.
- + Improved understanding of the following with a view to understanding which interventions work best to help people achieve safe, healthier, diets within a sustainable food system:
 - Individual / group behaviour throughout the global food supply chain (from producers to consumption and waste management) in the context of a broad range of food security drivers, such as environmental change, health, government intervention and technology development.
 - Food choice as determined by social and contextual factors (for example attitudes, values and cultural influence; demographic profile; the role of preference, habit and social practice; public understanding, advertising and marketing strategies), economic factors such as affordability, and biological factors (for example cognitive; food-reward mechanisms; satiety; palatability; and preference).

³⁵ Responsible innovation describes the process that helps researchers understand the benefits and risks of emerging technologies early on in the innovation process. It includes public engagement, risk management, life cycle analysis, ethical approval and regulation.

7. FUTURE PRIORITIES

88. Significant research and evidence gathering is being taken forward across all programme partners to help address the food security challenge, and GFS adds value by coordinating, aligning, integrating, influencing and shaping these activities.

89. Alongside coordination, GFS has a strong role in taking forward priority areas that would benefit from an interdisciplinary, food systems approach, and that would complement individual partner activities. A number of these areas are captured below and build directly on our engagement with key stakeholders, including policy, industry, NGOs and the public.

90. GFS will add value by:

- + Continuing to influence, shape and align existing and new activities across partners and stakeholders to maximise impact and value for money. We will also continue to horizon scan to identify emerging priorities, and exploit opportunities to address gaps in our knowledge.
- + Taking forward the development of the following priority areas that have scope for innovation through an interdisciplinary, food systems approach:
 - **Paris-compliant healthy food systems**
Helping to tackle climate change whilst improving nutrition by understanding interventions in the food system that would help meet the Paris Climate Agreement and deliver against the SDGs. This includes understanding what a future food system might look like, what would be grown and where, the role of technology, and what future diets might look like.
 - **Climatic shocks to the food system**
Helping to make the food system more resilient to shocks such as extreme weather and the reaching of tipping points by understanding how we can predict, mitigate and adapt to climatic shocks as well as to gradual climate change. This includes understanding the downstream impacts of sudden yield losses in terms of price shocks and how this is channelled through the food system via policy and markets to consumers.
 - **Behaviour change for adoption of a healthy and sustainable diet**
Helping to ensure the food system delivers improved outcomes for health and sustainability by understanding the determinants of dietary choices, the win-wins and trade-offs across health and sustainability, and the mix of interventions required for change across government, business and civil society.
 - **Sustainable management of natural resources in food production**
Helping to ensure food production is delivered alongside other ecosystem services within a multifunctional landscape by understanding trade-offs across the nexus of food, water, energy and environment and the role of new technologies, for example, using data from sensors and satellites to enable sustainable food production.
 - **Urban food systems**
Helping to ensure positive outcomes for health and sustainability from the rapid trend of urbanisation, in the context of food poverty and the nutrition transition, by understanding food demand and provision in cities, the demands on local resources, and the role of new technologies in urban agriculture.

- **The gut microbiome and its impact on health**
Helping to reduce overweight and obesity by understanding the role of the gut microbiome, the composition of microbes required for good health and mechanisms of action, the food stuffs that promote an appropriate diversity of gut microbes, and the impact of increasing homogenisation of global diets.
- **Post-EU referendum policy landscape**
Informing future UK food and farming policy through horizon scanning, synthesising existing knowledge and developing interdisciplinary research priorities.
- + **Working with international partners** to help deliver the research priorities above, identifying opportunities to work with food exporting nations, emerging economies and developing countries, including through mechanisms such as the Global Challenges Research Fund, the Newton Fund and the Prosperity Fund.
- + Continuing to **provide leadership and raise the profile** of the food security challenge and the GFS programme. GFS will continue to provide thought leadership, engage with key stakeholders and ensure that it is an authoritative source of information.
- + Working with the Strategy Advisory Board, Agri-Food Technology Council, Food Innovation Network and other similar groups to **maximise the impact** of our collective investments through innovation and knowledge exchange. Significant parts of the knowledge and evidence developed within the GFS programme will feed directly into, and help deliver government and industry strategies.
- + Continuing to raise awareness of evidence from research to inform stakeholder activities. In support of this aim, GFS will continue to publish *GFS Insight* **practice and policy notes** in key areas.
- + Building on our **public dialogue** and ensuring that public views, aspirations and concerns around global food security are factored into our activities.



Image credits:

All images usable under CC license <https://creativecommons.org/licenses/by-nc-nd/2.0/>

Kiwi Fruit - Sergiu Bacioiu, Flickr

Vegetables market – Markus Spiske, Flickr

Little Kids Eating Lunch at School – FatCamera, iStock

Apple conveyor belt – Jevtic, iStock

Floating Market, Bangkok – Ugurham Betin, iStock

Closeup of wooden spoon filled with wheat bran – Pogrebkov, iStock

Young Farmer checking the soil on his field – CasarsaGuru, iStock

Little girl helping mother shop for produce in grocery store – Asiseeit, iStock

Irrigation project – UK Department for International Development (DFID), Flickr

Haybale – Claus Rebler, Flickr

All other images courtesy of Thinkstock

Partners and affiliates



Innovate UK



wellcometrust

W www.foodsecurity.ac.uk

E info@foodsecurity.ac.uk