European Commission's

Scientific Advice Mechanism

A scoping review of major works relevant to scientific advice towards an EU sustainable food system

Scoping Review Report

Preparatory input to work by the European Commission's Group of Chief Scientific Advisors aimed at delivering science-based policy advice on realising a sustainable food system in the EU

25 February 2019

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Disclaimer

With their intention to develop a Scientific Opinion 'Towards an EU Sustainable Food System', the European Commission's Group of Chief Scientific Advisors asked the Scientific Advice Mechanism Unit to perform this scoping review. Its purpose is to provide an overview and high-level summary of the major, relevant work in this area to avoid duplicating existing analysis and advice and to help scope the intended scientific advice by the Group of Chief Scientific Advisors. While effort has been made to ensure accuracy and pertinence of the information included, no claim is made as to the perfection and completeness of the content.

Although staff of the Commission services participated in the preparation of the report and provided information and assistance in assembling it, the content may not in any circumstances be regarded as stating an official position of the European Commission.

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The SAM Unit wishes to thank the various scientific experts and expert practitioners, both within the European Commission and outside, who have helped identify major reports and additional sources of information.

1. BACKGROUND

SAM's Group of Chief Scientific Advisors (hereafter, Scientific Advisors) have identified the development of an EU sustainable food system as a high priority topic for future advice. It recognises the critical importance of the food system at the nexus of human health, climate change and environmental degradation. Further, the design of our food system has widespread implications for employment and incomes, animal welfare, trade and development. The Scientific Advisors believe that a new 'systems approach' to food is essential for the future security of supply in a changing world. The development of an EU sustainable food system also presents a 'golden opportunity' for the EU to play a significant role in efforts to achieve the UN's Sustainable Development Goals (SDGs).

2. PURPOSE

As the Scientific Advisors started to explore the topic of a sustainable food system, they noted the existence of a rich array of existing scientific reports and advice, as well as European Commission policy statements and initiatives, that are relevant to this topic. Being mindful to avoid duplicating existing analysis and advice, they instructed the SAM Secretariat (in September 2018) to undertake a 'stock-take' (scoping review) of major, relevant work in this area. The stock-taking exercise is based upon a review of existing major reports and initiatives, and evidence gathered in meetings with scientific experts and expert practitioners (European Commission and beyond). The main benefit of the scoping review has been to help the Scientific Advisors identify the questions that they might most useful address in order to contribute to the development of a sustainable food system in Europe. In addition, it is expected that the current report will be valuable to other parties interested in understanding the existing landscape of major works in this area.

3. METHOD AND SOURCES OF INFORMATION

This report is the product of a scoping review conducted by the SAM Unit in the European Commission over the course of about twelve weeks. The scoping review comprised: a (grey) literature search informed and aided by consultations with scientific experts and expert practitioners, a limited web search, and attendance at key (scientific) conferences. The resulting list of sources of information was then screened to focus upon existing major reviews and substantial reports and

initiatives that use a broad definition of a sustainable food system (see also Figure 1) and that have policy-relevant conclusions and/or recommendations. Different groups of experts were used to cross-check the sources selected to identify gaps and additional important sources. A final screening differentiated between major sources of information and supplementary sources of information (including scientific literature), with the latter mostly comprising studies and reports with valuable insights but of narrower scope than the major sources, with a less comprehensive analysis leading up to the recommendations, or with more limited policy-relevant recommendations (see Annex 1). Moreover, some works identified by the search were not taken up in this report, but may be used as future reference for subsequent work. Twelve major works were thus identified, specifically:

1. EASAC (European Academies Science Advisory Council), 2017, Opportunities and challenges for research on food and nutrition security and agriculture in Europe;
2. EC FOOD2030 (European Commission, Directorate-General for Research and Innovation), 2018, FOOD2030 - Recipe for change;
3. EEA (European Environment Agency), 2017, Food in a green light: A systems approach to sustainable food;
4. FAO (Food and Agriculture Organization of the United Nations), 2018, The future of food and agriculture: Alternative pathways to 2050;
5. Fresco & Poppe (Wageningen University & Research), 2016, Towards a Common Agricultural and Food Policy;
6. GO Science (UK Government Office for Science), 2011, The Future of Food and Farming;
7. IIASA (International Institute for Applied Systems Analysis), 2018, The World in 2050 Transformations to Achieve the Sustainable Development Goals;
8. IPES-Food (International Panel of Experts on Sustainable Food Systems), 2019, Towards A Common Food Policy for the EU;
9. STOA (Science and Technology Options Assessment), 2013, Technology options for feeding 10 billion people - Sustainable food and agriculture in the EU;
10. WRI (World Resources Institute, in partnership with the World Bank, UN Environment, UN Development Programme, CIRAD & INRA), 2018, World Resources Report, synthesis report: Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050;
11. WRR (The Netherlands Scientific Council for Government Policy), 2015, Towards a Food Policy;
12. Opinion of the EESC (European Economic and Social Committee), 2017, Civil society contribution to the development of a comprehensive food policy in the EU.

The last item by the EESC is not a scientific report *per se* but is written in the form of an Opinion; it is included here because of the high relevance of its scope and recommendations.

A full listing of all major and supplementary works that were included in this report feature in Annex 1. Some of the larger studies are comprised of several linked reports, from which the most relevant report was selected for review. For example, multiple related relevant reports have been published by the FAO, from which 'Alternative Pathways to 2050' was selected as the most relevant for the current scoping review.

Scientific conferences and meetings attended:

- European Food Safety Agency (EFSA) Conference 2018 "Science, Food, Society" - Parma, 19-21 September 2018
- World Food Day 2018 event "FOOD 2030: Research and Innovation for a "ZeroHunger World" – EU Parliament, Brussels, 16 October 2018
- Congress "Dialogue on sustainable food and agriculture: building a low-emissions future" - Brussels, 8 November 2018
- Austrian Presidency Conference "People's food - people's health: Towards healthy and sustainable European Food Systems" - Vienna, 22-23 November 2018

Also as a precursor to this scoping review:

- Telephone Conference between the Food and Agriculture Organisation (FAO) of the United Nations and the European Commission's Scientific Advice Mechanism (SAM) On Sustainable Food Systems - 28 May 2018
- Bulgarian Presidency Flagship Conference: 2nd Food 2030 High Level Event "Research and Innovation for Food and Nutrition Security – Transforming our food systems" - Plovdiv 14-15 June 2018

4. GENERAL OBSERVATIONS

The reports considered in the scoping review were found to vary in how they 'frame' the topic of a sustainable food system. For example, they differ in how broadly they define a food system i.e. which aspects they include in their analysis. Some focus mostly on the production of food, with some including input industry (seeds, fertiliser, etc.) and a few mentioning 'urban food production', where others emphasise the influence of food processors and retail sector in the food system. Most include the consumer-side, addressing food waste and dietary choices, with some covering food cultures and cuisines as well. Some focus just on agriculture, whilst others include food from the oceans and possible novel forms of protein production such as '*in vitro* meat' and the use of insects as food. Several argue that the food system must also encompass drinks/beverages, including alcohol and safe drinking water, in particular due to their very significant impact to health. The most comprehensive depictions of the food system identified in this review have been combined to a single overview in Figure 1.

The major reports also differ in how they define 'sustainability'. Some define sustainability only as achieving food security within environmental limits, whereas other reports consider additional aspects such as inequalities in access to food, viability of local producers and the maintenance of regional specific foods. Some cite the unsustainable burden of the current food system on the health system, as well as the environment, and note that these 'externalities' represent a failure of the standard economic model. Some link explicitly to the UN's Sustainable Development Goals (SDGs) to help to define the characteristics of a sustainable food system.

Overall, the scoping review confirmed the Scientific Advisors' initial impressions that there is already an established, large body of high-quality scientific reports and evidence-based (or at least evidence-informed) policy-relevant recommendations on this topic. The review also highlighted on-going relevant initiatives in the European Commission, most notably FOOD2030 that includes a series of policy-relevant recommendations and associated Research & Innovation requirements - all with associated on-going actions involving multiple stakeholders (see Annex 2). Furthermore, it noted the

relevant, high-level policy recommendations in the Opinion of the European Economic and Social Committee (2017) on the civil society's contribution to the development of a comprehensive food policy. Additionally, the final report of the International Panel of Experts on Sustainable Food Systems (IPES-Food) provides highly detailed short- and long-term recommendations on relevant EU policies, as well as on global, national and regional matters. Also worth highlighting is the recent Policy Brief prepared in support of the Austrian European Council Presidency, which already goes some way in linking currently diverse food system-relevant policy goals of the European Commission to identify potential co-benefits.

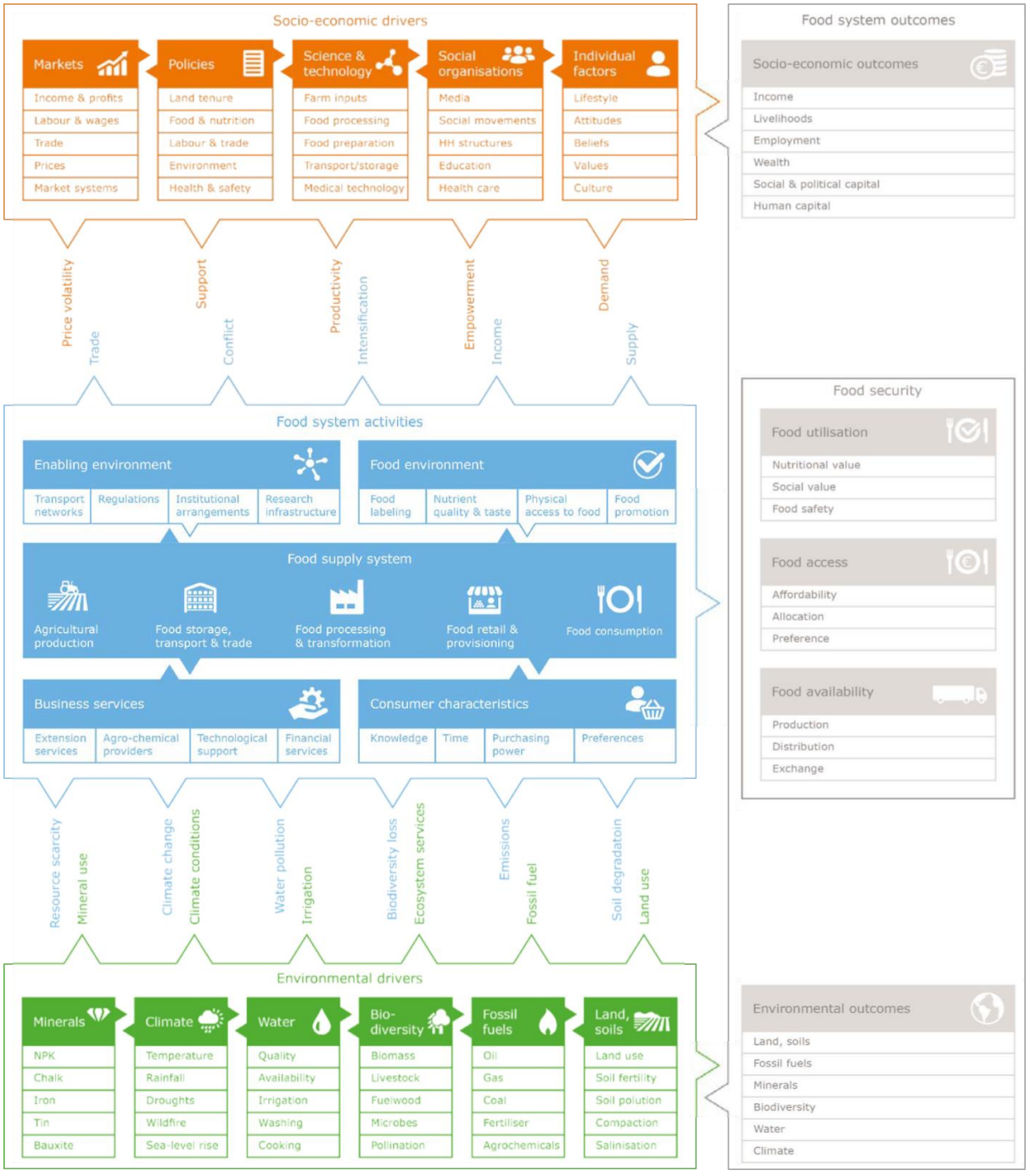

Figure 1 – The food system, with a mapping of the relationships between drivers, activities and outcomes
(Source: adapted from Wageningen Economic Research, 2018)

5. THE USE OF MODELS AND SCENARIOS

Many of the works reviewed include systematic analyses of trends and make use of computer models to produce projections of possible future states of the food system to 2030 or 2050. Some of these use socio-economic scenarios to explore possible different futures under different pressures (both negative and positive). Such future projections are an essential part of assessing sustainability of policies and practices into the future where the food system is subject to trends, such as changes in demand (population and/or diets), losses/waste, and rates of production.

Integrated impact assessment models are generally used to analyse the economic, social and environmental impacts of food system policies and practices and to explore a system's sustainability and resilience under a range of projections and scenarios. The models are composed of modules that consider the above dimensions as well as biophysical processes and operate at different time and spatial scales.

Although most of the established modelling frameworks are characterised by a substantial degree of plausibility, their complexity and data limitations mean that their outputs are subject to inherent uncertainties. However, this review finds that these uncertainties are rarely reported with sufficient rigor. Whilst integrated impact assessment modelling is a widely used tool that undoubtedly provides valuable insights into social, economic and environmental impacts of policies and practices, the inherent uncertainties of the models mean that their results should be interpreted with care. On-going efforts to improve model reliability and the accuracy of reporting is noted and is expected to improve this situation over time.

Despite the use of different underlying modelling methods and assumptions (each associated with specific inherent uncertainties), the outcomes of the various future projections do show a high degree of similarity, at least regarding direction and order of magnitude. This is comforting and provides some additional confidence in the likely validity of the conclusions.

6. THE IDENTIFIED MAIN CHALLENGES TO FOOD SYSTEMS

The works reviewed identify highly similar main challenges (disruptors, pressures, vulnerabilities) to food systems (now and in the future), and commonly highlight the urgency to act upon these now and in a cohesive manner. A summary of these main challenges is provided below:

- **Expanding global population** (towards 10 billion in 2050), combined with **demographic transformations**, including increased urbanisation (70% in 2050), migration (amplified further by climate change), and rural ageing, against a background of an uneven distribution of food with a persistent inability to eradicate hunger;
- **Climate change** causing higher temperatures and increased frequency and severity of extreme weather events (drought and floods), resulting in in lower yields and harvest losses, changes in abundance and distribution of harvested freshwater and marine species, and increases in incidences of pests and diseases;
- Socio-economic trends leading to **unhealthy and unsustainable food consumption** with increased demand for livestock products, and calorie-dense, nutrient-poor and (hyper-)processed food, resulting in rising levels of overweight, obesity and diet-related (non-communicable) diseases, as well as in unsustainable land and water use, increased greenhouse gas emissions and other pollution, and the development and spread of zoonoses and multi-resistant bacteria;
- **Depletion of natural resources and exploitation beyond environmental limits**, including loss of biodiversity and ecosystem services, decline of available agricultural land through soil erosion/degradation and long-term decreases in soil organic carbon (SOC), diminishing stocks of clean, fresh water, overexploitation of marine and freshwater fisheries, ocean acidification, eutrophication through nutrient overload, air and water pollution, deforestation, and competing demands on agricultural land (urbanisation, infrastructure, biofuels/biomaterial);
- **Geo-political events and shocks** caused by increased conflict, often over scarcity of raw materials, land, water and energy, and by climate change effects (including migration) as well as civil disturbances arising from inequality combined with price volatility on global energy/agricultural markets.

Concerns are also raised about the low resilience of food systems resulting from decreased variety of crop species and livestock breeds, protectionist market responses during times of (perceived) crises, and the unevenly distributed power in the food value chain with power concentrated in the hands of a few companies.

7. SUMMARY OF THE WORKS' MAIN RECOMMENDATIONS

Despite differences in approaches, the major works all tend towards the same main conclusions with only relatively small differences in their analysis of the challenges posed to food security, the environment, public health, socio-economic and cultural aspects. Where they differ, this is often in scope, such that their analyses are generally complementary and not contradictory. Importantly, the high-level recommendations of the works also exhibit a large degree of consensus and complementarity on what needs to be done (recommendations) to establish a sustainable food system, albeit to different degrees of detail.

More specifically, there is a broad consensus that a synergistic combination of policies and actions is required, which:

- promote **sustainable intensification**: increasing yields and efficiency, while decreasing environmental burden (on biodiversity, soils, water and air);
- reduce **food loss and waste**, while encouraging reuse and recycling of unavoidable food waste;
- stimulate **dietary changes** towards healthier, less resource-intensive and more plant-based diets;
- improve the **resilience and robustness** of the food system, in particular by diversification, to cope with shocks from geopolitical developments and to adapt to the effects of climate change;
- increase the **accountability and stewardship** of producers and consumers on the environmental, economic, social and public health effects of the food system, among others through participatory policy development and monitoring, increased transparency, training/education and improved labelling to better inform consumer choices.

Albeit not a specific recommendation in itself, a reoccurring point made in several of the reviewed works is that we must **pay the true costs of food**, which is currently not the case. This means that the aspects now seen as 'externalities', e.g. negative impacts on the environment and on public health, should be internalised into the price of the food to have a properly functioning food market. Some do remark that this must go hand-in-hand with ensuring food affordability to the poorest (which some highlight as an essential aspect of a fair transition to a sustainable food system).

Additionally, most works reviewed recommend greater cohesion between different, relevant policy areas (as a prerequisite for effective measures), focussing on co-benefits rather than conflicting policies, and several reports recommending the establishment of an EU common food/nutrition policy as a means to achieve policy integration (see Table 1). Despite the clear complexity of the food system, many works identify relatively clear and apparently tractable solutions. These range from city- and community-based initiatives to EU and global (e.g. WTO) initiatives and/or policies.

Table 1 – Summary of recommendations of the reviewed works
See also Annex 3 for a more elaborate table with specific quoted examples

	1. sustainable intensification	2. food loss/waste	3. dietary changes	4. resilience/ robustness	5. accountability/ stewardship	policy cohesion (C) / integration (I)
1. EASAC 2017	+ +	+ +	+ +	+	+ +	**I**
2. EC FOOD2030 2018	+ +	+ +	+ +	+ +	+ +	**I**
3. EEA 2017	+	+ +	+ +			**C**
4. FAO 2018	+ +	+ +	+ +	+ +	+ +	
5. Fresco & Poppe 2016	+	+ +	+ +	+ +	+ +	**I**
6. GO Science 2011	+ +	+ +	+ +	+	+ +	**C**
7. IIASA 2018	+ +	+ +	+ +	+ +	+ +	**C**
8. IPES-Food 2019	+	+ +	+ +	+ +	+ +	**I**
9. STOA 2013	+ +	+ +	+ +	+ +	+ +	**C**
10. WRR 2015	+	+ +	+	+ +	+ +	**I**
11. WRI 2018	+ +	+ +	+ +	+	+ +	**C**
12. EESC 2017 (Opinion)	+ +	+ +	+ +	+ +	+ +	**I**
13. Agrimonde 2009	+	+ +	+ +	+	+ +	**C**
14. Drawdown 2017	+	+ +	+ +	+		
15. FAO & WHO 2014	+	+ +	+ +	+ +	+ +	**C**
16. GLOPAN 2016	+	+ +	+ +	+ +	+ +	**C**
17. HLPE 2017	+	+ +	+	+	+ +	**C**
18. IPCC 2014	+			+ +		**C**
19. Parsons & Hawkes 2018	+	+ +	+			**C**
20. Wageningen Economic Research 2018	+	+ +	+ +	+	+	**C**
21. EAT-Lancet Commission 2019	+ +	+ +	+ +	+ +	+ +	**C**
22. Krishna Bahadur et al. 2018	+ +	+ +	+ +			
23. Lancet Global Syndemic Commission 2019			+ +	+	+ +	**I**
24. Springmann et al. 2018	+	+ +	+ +			**C**

Considering this is a very rich and fast-growing area, it is acknowledged that the current scoping review does not comprehensively cover all relevant works; necessarily focussing on just the most pertinent works identified within the frame and timescale of the review. However, the overall agreement in conclusions of those reviewed provides confidence in the validity of the findings. Whilst there has been a sharing of views and information between the authors of some of the major reports

reviewed, as well as (cross-)referencing, this is by no means true in all cases. Rather the overall convergence of conclusions and recommendations reflects that the separate calls for a sustainable food system are driven by strong evidence, now widely recognised, that the current food system is neither future-proof nor equitable. Moreover, there is wide recognition that a cross-cutting, multi-actor approach is essential to address systemic issues like food waste, obesity/malnutrition, lack of resilience to climate change, etc. Furthermore, the SDGs are recognised by experts as contributing to the sense of urgency for action and momentum to share that message among a broad range of stakeholders, including citizens, city leaders (e.g. the Milan Urban Food Policy Pact), and the private sector (e.g. World Economic Forum).

It should be highlighted that all of the major works acknowledge there is no single formula or 'silver bullet' for action, and that multiple simultaneous actions from multiple actors are considered in all cases to be essential. It is also broadly recognised that local or regional conditions will determine which specific actions are most likely to be the most successful in each setting.

8. DISCUSSION AND CONCLUSION

In summary, the works that have been analysed as part of this review, collectively contain a wealth of well-evidenced, policy-relevant recommendations, often coupled with supporting research and innovation needs. This includes the Commission's own FOOD2030 initiative, which includes a broad definition of a sustainable food system, reflects many of these recommendations, and presents them in a manner designed to fit with already stated European Commission food or food-related policies, initiatives and organisational groups.

Overall, SAM finds that the existing reports, conference outputs, and on-going initiatives present a rather comprehensive suite of recommendations and opinions. Moreover, the reports have been produced with expert analysis and input, and are of high quality. Where some aspects of the modelling work would benefit from greater transparency with respect to uncertainties contained therein, this does not appear to detract from the overall recommendations of the reports.

The scoping review has also highlighted the scale of the challenge facing the EU in its commitment to move towards a sustainable food system. Although a "sustainable food system" has not yet emerged explicitly as a goal, many policy commitments partially address this, including the SDGs, the Europe 2020 strategy, the Environmental Action Programme (7th EAP), the Paris Agreement, etc. Moreover, the ambition of an EU sustainable food system features prominently in the recent European Commission reflection paper "Towards a Sustainable Europe by 2030". For the EU to achieve such a systemic change is a major and complex challenge (for an overview of existing relevant EU policy goals that may contribute towards this end, see Figure 2 and for links between challenges and international and EU policies see Annex 2).

In conclusion, the largest remaining 'gap' in high-level scientific advice appears to relate not to 'what' needs to be done to develop a sustainable food system for Europe, but rather 'how' such a transition can best be achieved. Specifically, there appears to be a 'social sciences deficit' in the major works reviewed, which critically needs to be addressed. In other words, how can the EU help ensure that its activities or policies towards achieving a sustainable food system will be as effective as possible? Whilst the EESC Opinion of 2017 ("Civil society's contribution to the development of a comprehensive food policy") contains valuable insights and makes 'in-roads' into this area, and the

Policy Brief "Connecting food systems for co-benefits" provides a good starting point to collaborate on diverse policy goals, there is still work to be done. More specifically, gaps still exist in EU-level scientific advice on 'what works' – that considers aspects such as barriers to change and insights into changing behaviours, to provide practical advice on the most effective transitional pathways. Perhaps most significant is the gap in advice on how to achieve a 'just' (fair) transition to a sustainable food system in the EU, to provide optimal benefit to EU citizens.

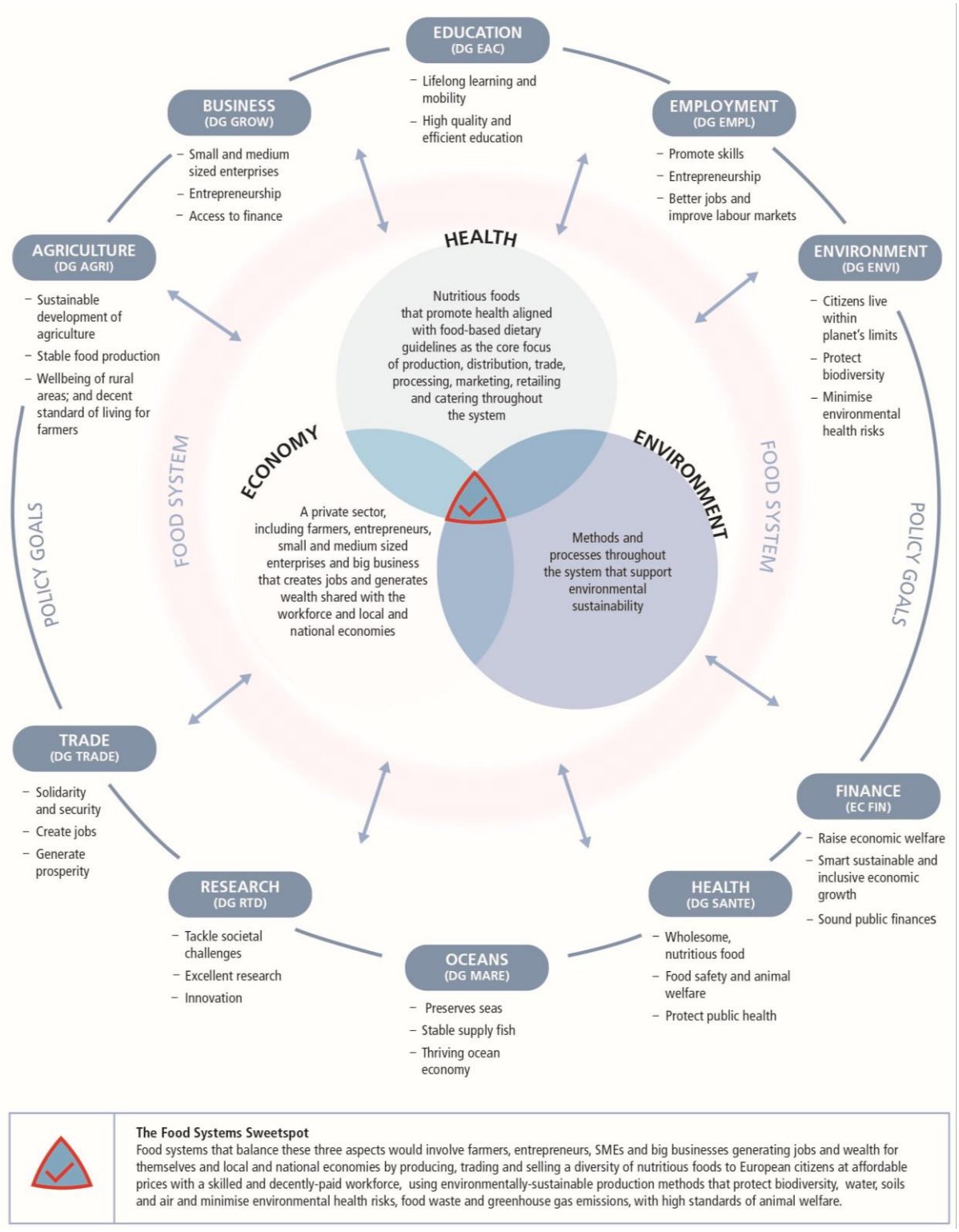

Figure 2 – EU policies goals relevant to the food system, highlighting co-benefits
(Reprinted with permission from "Connecting food systems for co-benefits: How can food systems combine diet-related health with environmental and economic policy goals?", Policy Brief 31, K. Parsons & C. Hawkes, ©2018)

Annex 1 - List of reviewed works

Most relevant major works:

1. EASAC (European Academies Science Advisory Council), 2017, Opportunities and challenges for research on food and nutrition security and agriculture in Europe (https://easac.eu/publications/details/opportunities-and-challenges-for-research-on-food-and-nutrition-security-and-agriculture-in-europe/);
2. EC FOOD2030 (European Commission, Directorate-General for Research and Innovation), 2018, FOOD2030 - Recipe for change (https://publications.europa.eu/en/publication-detail/-/publication/d0c725de-6f7c-11e8-9483-01aa75ed71a1/language-en);
3. EEA (European Environment Agency), 2017, Food in a green light: A systems approach to sustainable food (https://www.eea.europa.eu/publications/food-in-a-green-light);
4. FAO (Food and Agriculture Organization of the United Nations), 2018, The future of food and agriculture: Alternative pathways to 2050 (http://www.fao.org/publications/fofa);
5. Fresco & Poppe (Wageningen University & Research), 2016, Towards a Common Agricultural and Food Policy (http://edepot.wur.nl/390280);
6. GO Science (UK Government Office for Science), 2011, The Future of Food and Farming (https://www.gov.uk/government/publications/future-of-food-and-farming);
7. IIASA (International Institute for Applied Systems Analysis), 2018, The World in 2050 Transformations to Achieve the Sustainable Development Goals (http://pure.iiasa.ac.at/15347);
8. IPES-Food (International Panel of Experts on Sustainable Food Systems), 2019, Towards A Common Food Policy for the EU (http://www.ipes-food.org/_img/upload/files/CFP_FullReport.pdf);
9. STOA (Science and Technology Options Assessment), 2013, Technology options for feeding 10 billion people - Sustainable food and agriculture in the EU (http://www.europarl.europa.eu/RegData/etudes/etudes/join/2013/513539/IPOL-JOIN_ET(2013)513539_EN.pdf);
10. WRI (World Resources Institute, in partnership with the World Bank, UN Environment, UN Development Programme, CIRAD & INRA), 2018, World Resources Report, synthesis report: Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050 (https://www.wri.org/publication/creating-sustainable-food-future);
11. WRR (The Netherlands Scientific Council for Government Policy), 2015, Towards a Food Policy (https://english.wrr.nl/publications/reports/2016/12/13/towards-a-food-policy);
12. Opinion of the EESC (European Economic and Social Committee), 2017, Civil society contribution to the development of a comprehensive food policy in the EU (https://www.eesc.europa.eu/en/our-work/opinions-information-reports/opinions/civil-societys-contribution-development-comprehensive-food-policy-eu).

Selection of supplementary works:

13. Agrimonde (CIRAD & INRA), 2009, Scenarios and Challenges for Feeding the World in 2050 (https://www.cirad.fr/en/content/download/3796/35063/version/7/file/1209Agrimonde_SummaryReport.pdf);
14. Drawdown (Hawken *et al.*), 2017, The Most Comprehensive Plan Ever Proposed to Reverse Global Warming (https://www.drawdown.org/the-book), complemented with a Project Drawdown presentation and website consultation in 2019;

15. FAO & WHO (Food and Agriculture Organization of the United Nations & World Health Organization), 2014, Second International Conference on Nutrition (Rome, 19-21 November 2014) - Conference Outcome Document: Framework for Action (http://www.fao.org/3/a-ml542e.pdf);
16. GLOPAN (Global Panel on Agriculture and Food Systems for Nutrition), 2016, Food systems and diets: Facing the challenges of the 21st century (http://glopan.org/sites/default/files/ForesightReport.pdf);
17. HLPE (High Level Panel of Experts on Food Security and Nutrition), 2017, Nutrition and food systems (http://www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE_Reports/HLPE-Report-12_EN.pdf);
18. IPCC (Intergovernmental Panel on Climate Change), 2014, Food security and food production systems. Chapter 7 in the Fifth Assessment Report of the IPCC (https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap7_FINAL.pdf);
19. Parsons & Hawkes (European Observatory on Health Systems and Policies), 2018, Connecting food systems for co-benefits: how can food systems combine diet-related health with environmental and economic policy goals? - Policy Brief 31 (http://www.euro.who.int/en/about-us/partners/observatory/publications/policy-briefs-and-summaries/connecting-food-systems-for-co-benefits-how-can-food-systems-combine-diet-related-health-with-environmental-and-economic-policy-goals);
20. Wageningen Economic Research, 2018, The food systems approach: sustainable solutions for a sufficient supply of healthy food (http://library.wur.nl/WebQuery/wurpubs/fulltext/451505).

Selection of notable scientific articles:

21. EAT-Lancet Commission (Willett *et al.* in *The Lancet*), 2019, Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems (https://doi.org/10.1016/S0140-6736(18)31788-4);
22. Krishna Bahadur et al. (in *PLOS ONE*), 2018, When too much isn't enough: Does current food production meet global nutritional needs? (https://doi.org/10.1371/journal.pone.0205683);
23. Lancet Global Syndemic Commission (Swinburn *et al.* in *The Lancet*), 2019, The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report (https://doi.org/10.1016/S0140-6736(18)32822-8);
24. Springmann *et al.* (in *Nature*), 2018, Options for keeping the food system within environmental limit (https://doi.org/10.1038/s41586-018-0594-0).

Annex 2 – Outline of challenges and relevant European and international policies, with associated R&I requirements identified in the EC's FOOD2030 initiative

CHALLENGES	R&I PRIORITIES	RELEVANT POLICIES
NUTRITION & HEALTH		
Malnutrition and hunger Obesity and the rise of non-communicable diseases Food safety issues and crises Rising protein demand Unhealthy and unsustainable diets	Sustainable and healthy diets Personalised nutrition Alternative proteins sources Sustainable aquaculture for greater seafood uptake Nutrient enriched foods Public health systems, societal awareness, consumer behaviour Food safety and traceability	UN SDGs 2, 3 & 6 WHO Health policies EU-Global Food Security EU-Blue Growth Strategy EU-Food Safety Policy EU-Health Policy EU-Global Food Security Policy
CLIMATE & SUSTAINABILITY		
Food systems not resilient to changing climate Ensure food quantity and quality in a changing climate Ensure food systems also contribute to mitigating GhG emissions Food scarcity and poverty-induced migration Protect biodiversity	Climate Smart food systems that mitigate and adapt to climate change, while ensuring environmental sustainability GHG mitigation via good soil management and demand-side approaches Drought and flood resistant crops Pest management in a changing climate Biodiversity conservation Biofertilizers Agro ecological intensification Soil, water and land remediation Healthy plants and animals	UN SDGs 11, 13 & 14 COP21 Climate Change EU-Global Food Security EU-Common Agricultural Policy EU-Rural Development Fund EU-Common Fisheries Policy EU-Development Cooperation EU-Environment Policies (Marine Strategy Framework Directive, Water Framework Directive) EU-Conservation policies

CHALLENGES	R&I PRIORITIES	RELEVANT POLICIES
CIRCULARITY & RESOURCE EFFICIENCY		
Resource efficiency in food systems Environmentally sustainable food systems Healthy ecosystems to provide sustainable ecosystems services for food production Polluted ecosystems suffering from intensive production practices Limit or reuse food waste for multiple uses	Increase resource efficiency and circularity (land, water, energy, soil, fertilizers, etc) across the food system Reduction and multiple uses of food losses and waste Reuse of fish discards Reuse of fodder for enhancing soil organic matter and reducing soil erosion Smart precision farming to reduce agricultural inputs	UN SDGs 7 & 12 COP21 Climate Change EU-Common Agricultural Policy EU-Rural Development Fund EU-Common Fisheries Policy EU-Environment Policies (MSFD, WFD, Circular Economy Package) EU-Global Food Security Policy
	INNOVATION & COMMUNITIES	
Make food systems sustainable, resilient, responsible, diverse, competitive and inclusive Empower and engage communities, civil society and consumers in food systems Strengthen rural, urban and coastal communities around food and nutrition security Increase the level of food and nutrition literacy of consumers Unsustainable and unhealthy consumer behaviour Boost new skills, jobs and business models for better functioning food systems	Boosting innovation Empowering communities and consumers in FNS Food in cities: water, energy, health nexus. Short circuits Boosting investment in public and private sector R&I FNS Encouraging Responsible Research and Innovation in food systems Open Science and access to data and information in FNS Quadruple helix innovation, multi-actor and public engagement in food systems Education, skills development and capacity building in FNS and food science New sources of income for farmers and fishers New business models and inclusive/open/eco-/sustainable innovation FNS start-up financing	SDGs 1, 8, 9 & 11 COP21 Climate Change EU-Global Food Security EU-European Fund for Strategic Investment EU-Common Agricultural Policy EU-Rural Development Fund EU-European Structural and Investment Funds EU-Common Fisheries Policy EU-Food Safety Policy EU-Environment Policies (WFD, Circular Economy Package)

Annex 3 – Overview of recurring recommendations in reviewed works with quoted examples

Most relevant major works:

	sustainable intensification	food loss/waste	dietary changes	resilience/ robustness	accountability/ stewardship	policy integration/ cohesion
1. EASAC 2017	efforts to increase the efficiency of food systems should not focus on increasing agricultural productivity by ignoring environmental costs	novel approaches to processing food and reducing waste	introducing new incentives for healthy nutrition; reduce meat consumption	regulatory and management frameworks are evidence-based, proportionate and sufficiently flexible; crop diversification	clarifying what is a sustainable, healthy diet; resolution of international governance issues of food and agriculture	move from the present CAP towards food and nutrition policy that rewards innovation
2. EC FOOD2030 2018	Create a resource-smart food system with 50% lower greenhouse-gas emissions by 2030; double the sustainable production of high-quality food from EU aquatic systems by 2030	Halve food waste and losses from the EU food and farming system by 2030	Improve dietary patterns and lifestyles for a 50% reduction in the incidence of non-communicable diseases (NCD) in 2030, while reducing the environmental impact of food consumption	diversify fields, farms, landscapes and diets to use resources in a climate-proof, sustainable way; Resilient: adapting to climate and global change, including extreme events and migration	strengthen the different roles of citizens in a healthy, diverse and sustainable food system; link cities, remote rural and coastal areas to help them develop innovative food systems; improve international cooperation in trade	develop a unified, health-centric, climate-smart, sustainable and resilient food system for Europe based on a system approach; Work closely with other EC services, and others
3. EEA 2017	Innovative production methods are called for, with sustainable use of natural resources such as land, soils and ecosystems and emission reduction measures at their core	more effective distribution chains, and food waste prevention	Dietary shifts towards less resource-intensive products (more plant based, less refined)			Call for policy cohesion

4. FAO 2018	sustainable intensification: sustainable agricultural practices might require forgoing certain yield increases, particularly when such increases lead to the overuse of water resources, a reduction in soil fertility, the loss of biodiversity and higher GHG emissions	reduce food waste and loss considerably	Dietary patterns of high-income countries need balancing; consume less animal products	Agricultural sectors can adapt to climate change and lower their GHG emissions while producing enough food for all with substantial investments for resource-saving and climate-friendly technologies	education and raising consumer awareness on environmentally sustainable diets, the nutritional content of food and diet-related diseases; Food prices should reflect nutritional value of food as well as environmental costs.	
5. Fresco & Poppe 2016	incentives to produce eco-system services but also to accommodate resource-efficient intensification	a stronger incentive to reduce food waste, especially for consumers, who, in Western countries, are the main culprits; resource-use efficiency; better use of farm, slaughter, feed and food waste in order to move towards a true circular and bio-based economy	Make our diets more healthy and sustainable with a price that factors in true cost	An explicit targeting of farmers is needed in the agricultural and food policy to help mitigate the effects of climate change; reinforce the resilience of the entire food chain; develop risk management strategies	instruments, including education and advice, procurement strategies and consumer nudging; consumers could become strong allies of farmers and both can help to provide checks and balances in the food chain; stewardship of the landscape and biodiversity can be defined and rewarded according to specific criteria	we need to develop the CAP into a Common Agricultural and Food Policy
6. GO Science 2011	Promote sustainable intensification: requires economic and social changes to recognise the multiple outputs required of land managers, farmers and other food producers, and a redirection of research to address a more complex set of goals than just increasing yield	Reduce waste – particularly in high- and low-income countries	consider the full range of options to change consumption patterns, including raising citizen awareness, approaches based on behavioural psychology, voluntary agreements with the private sector, and regulatory and fiscal measures	Incentives to encourage greater efficiency of water use and the development of integrated water management plans need to be given high priority	tools to help citizens hold all other actors (and themselves) to account for their efforts to improve the global food system; Make sustainable food production central in development; Include the environment in food system economics	action needs to be sustained and coherent, and championed at high level

7. IIASA 2018	providing more and healthier food through sustainable intensification on existing farmland, returning land to nature; careful management of land use, oceans, and other environmental resources; removal of subsidies for unhealthy and environmentally harmful production techniques	Reducing food loss and food waste is one promising way to reduce the environmental pressure from, and vulnerability of, current food systems	less resource-intensive diets; dietary changes toward less meat-intensive diets; reductions in beef consumption can promote human health while also protecting the environment	build resilience into agricultural production; modification of agricultural practices to minimize environmental damage and maximize resilience	encourage healthier diets through public awareness campaigns; transparent and accountable global economic governance; Building transformative alliances across sectors and public spheres (state, market and civil society) from local to global	comprehensive planning towards a transformation to attain all SDGs; government-led integrated planning; enhance policy coherence across sectors, levels and actors
8. IPES-Food 2019	move towards comprehensive protection of natural resources under a Land and Soil Directive; incentivizing nitrogen-fixing legumes, pastures and agroforestry, putting independent farm advisory services in place, promoting farmer-to-farmer knowledge sharing, and ultimately phasing out the routine use of chemical inputs	Target reduced production of waste via supply chain redesign (incl. short supply chains) under review of Circular Economy Package	Promoting sufficient, healthy and sustainable diets for all	Rebuilding climate-resilient, healthy agro-ecosystems; low-input, diversified agroecological systems	reconnect food system actors (e.g. producers and consumers, citizens and local policymakers) in a way that restores democracy, accountability, and trust in food systems; widespread participation into all policies affecting food systems; make investors and multinational firms accountable for the sustainability of their supply chains	Significant policy reform and realignment is required in a range of areas under a Common Food Policy; Integration across policy areas; Integration across governance levels

9. STOA 2013	Provide appropriate incentives for climate resilient and biodiversity-friendly forms of farm management that also maintain and increase productivity; Constrain unsustainable agricultural practices which have damaging environmental effects	Reduce food losses and increase food supply chain sustainability; Reuse unavoidable food wastes and residues for biomaterials and bioenergy	A reduction in meat and dairy consumption in developed countries	incentives for the adoption of management actions that have benefits for climate change adaptation and mitigation; greater focus on maintaining and enhancing soil fertility and the resilience of farming systems	Increase the awareness of producers and consumers in the food chain	the goal of sustainable food security for all is not possible without action on all of these issues, because the challenges are so great and the risk of failure needs to be spread
10. WRI 2018	Raise productivity; Link agricultural intensification with natural ecosystems protection; Improve productivity and environmental performance of aquaculture	Reduce food loss and waste	Shift to healthier and more sustainable diets; from high meat consumption toward plant-based foods	Adapt to climate change	Many food producers, processors, and vast numbers of consumers will need to take a variety of actions; maximizing awareness, and evolving social norms; Supply chain commitments	Cross-cutting policies for a sustainable food future
11. WRR 2015	organising sustainable management of resources; review EU competition law	Reduce waste and to re-use residual flows at the highest possible value	alternative protein sources	a variety of players, but also of crop species, animal breeds and materials	learning capacity and adaptability on the part of all players	From an agricultural policy towards a food policy
12. EESC 2017	more sustainable food production	promote food waste prevention and reduction	encouraging healthier and more sustainable food consumption	resilient food systems need to maintain a mix of large and small farm enterprises	engaged consumers to become active food citizens; a new concept of food citizenship around eating for sustainability; new smart system on sustainable food labelling; EU sustainable food scoreboard	development of a comprehensive food policy in the EU, with the aim of providing healthy diets from sustainable food systems; dedicated DG for Food

Selection of supplementary works:

	sustainable intensification	food loss/waste	dietary changes	resilience/ robustness	accountability/ stewardship	policy integration/ cohesion
13. Agrimonde 2009	farming techniques and work organization should lead to improvements in the use of inputs and to crop diversification, while improving the quality of soils and water, enriching biodiversity and guaranteeing adequate and stable returns on investments	reduction in waste and losses at all stages of the food chain, from field to plate	transition from current diets to healthier and more diversified diets; more coarse grains, legumes, fruit and vegetables, and less animal products in diets in most regions of the world	crop diversification	education accelerate progress towards healthy diets and the reduction of consumption waste and losses; facilitate evolution of multilateral trading system towards clear rules and increased openness and transparency and to link trade agreements to environment, food security issues etc.	changing the course of ongoing trends requires systemic transformation, public policies and consistent actions from a wide range of actors
14. Drawdown 2017	System of Rice Intensification; Nutrient Management; Regenerative Agriculture; Tree Intercropping; Silvopasture; Tropical Staple Trees; Composting; Farmland Irrigation	Reduced Food Waste	Plant-Rich Diet	Conservation Agriculture; Regenerative Agriculture; Multistrata Agroforestry; Tree Intercropping; Silvopasture; Tropical Staple Trees; Improved Rice Cultivation; Farmland Irrigation		

15. FAO & WHO 2014	applying sustainable food production and natural resource management practices;	Improve storage, preservation, transport and distribution technologies and infrastructure to reduce seasonal food insecurity, food and nutrient loss and waste	Encourage gradual reduction of saturated fat, sugars and salt/sodium and trans-fat from foods and beverages to prevent excessive intake by consumers and improve nutrient content of foods, as needed	Establish and strengthen institutions, policies, programmes and services to enhance the resilience of the food supply in crisis-prone areas, including areas affected by climate change	Enhance political commitment and social participation for improving nutrition at the country level through political dialogue and advocacy; Improve the availability, quality, quantity, coverage and management of multi-sectoral information systems related to food and nutrition for improved policy development and accountability	Strengthen and establish, as appropriate, national cross-government, inter-sector, multi-stakeholder mechanisms for food security and nutrition to oversee implementation of policies, strategies, programmes and other investments in nutrition
16. GLOPAN 2016	Invest in nutrition-enhancing agricultural productivity growth; build sustainability into the country's agricultural system, conserving limited water supplies and promoting long-term management of soils, forests and biodiversity	reducing food losses and waste	Increase fruit and vegetable intake; Increase intake of legumes/pulses; Increase intake of grains high in protein, micronutrients and fibre; Encourage balanced consumption of safe milk; Replace trans-fats with unsaturated fats; Reduce intake of sugary drinks	Food system policies must be developed which are resilient to future long-term threats and uncertainties (Changes in the size and age distribution of populations, Climate change, Rapid urbanization, Income growth, Globalization of diets, Competition for natural resources)	Improve accountability at all levels (governments, private sector actors, civil society organizations	Break down barriers associated with the longstanding division of jurisdictional responsibilities within many governments – between agriculture, health, social protection and commerce

17. HLPE 2017	providing incentives for agro-ecological and other types of environmentally-friendly farming practices	promoting practices and technologies to improve food safety and reduce food quality losses and waste	Implement economic and social policies that increase demand for nutritious foods and lower demand for nutrient-poor foods; Ensure the food supply is healthy for the consumer; promoting nutritious foods and sustainable diets along food supply chains	Avert devastating, costly famines, by strengthening local food systems and longer-term development support, and by investing in humanitarian aid that supports communities' capacities and resilience	Ensure transparency and accountability mechanisms; Improve the availability and quality of multi-sectoral information systems that capture diet, food composition and nutrition-related data for improved policy development and accountability; Invest in participatory systems for the sharing of knowledge and best practices among stakeholders in the food supply chain; Improve food and nutrition literacy throughout society	Integrate a nutrition-focused food system approach into national development, health and economic plans; Foster policy coherence in order to improve diets and nutrition, through enhanced coordination across sectors, including agriculture, environment, energy, water, sanitation and hygiene (WASH), health, education, fiscal policies, economic and social development
18. IPCC 2014	measures that reduce soil erosion and loss of nutrients such as nitrogen and phosphorus and for increasing soil carbon, conserving soil moisture, and reducing temperature extremes by increasing vegetative cover			adaptation of food systems to climate change will be necessary. Here we take adaptation to mean reductions in risk and vulnerability through the actions of adjusting practices, processes, and capital in response to the actuality or threat of climate change		large opportunity costs that could arise from not considering more systemic adaptation or more transformative change
19. Parsons & Hawkes 2018	using environmentally-sustainable production methods; stable supply of affordable food	less food waste	Nutritious foods that promote health and align with food-based dietary guidelines; less exposure to the availability and marketing of foods high in fats, sugars and salt			cross-government coordination mechanisms; Food systems policy roundtables; produce co-benefits for more than one policy goal

20. Wageningen Economic Research 2018	changes in agricultural production designed to remain within the environmental limits of the system	reducing waste and/or recycling minerals and food remains as animal feed or compost (circularity); improve post-harvest management: the storage, processing and transport of food products in the chain; increase consumer awareness of their purchasing and consumption behaviour in order to tackle waste	providing information about what people need in terms of nutrition (dietary guidelines); a dietary change from meat to plant products	FSA a useful perspective in the literature on the resilience (robustness) of the food production system, which is about the capacity of the system to absorb shocks	alerting consumers to the environmental impact of food-wasting behaviour	benefits of systems thinking

Selection of notable scientific articles:

	sustainable intensification	**food loss/waste**	**dietary changes**	**resilience/ robustness**	**accountability/ stewardship**	**policy integration/ cohesion**
21. EAT-Lancet Commission 2019	Sustainably intensify food production to increase high-quality output	Substantially reducing the amount of food lost and wasted across the food supply chain, from production to consumption	substantial shifts towards healthy dietary patterns; a diversity of plant-based foods, low amounts of animal source foods, unsaturated rather than saturated fats, and small amounts of refined grains, highly processed foods, and added sugars	adopting a Half Earth strategy for biodiversity conservation to safeguard resilience and productivity in food production	adoption of scientific targets by all sectors to stimulate a range of actions from individuals and organisations working in all sectors and at all scales; investment in public health information and sustainability education	improved coordination between departments of health and environment; Strong and coordinated governance of land and oceans; An opportunity exists to integrate food systems into international, national, and business policy frameworks aiming for improved human health and environmental sustainability

22. Krishna Bahadur et al. 2018	Increasing production of fruits and vegetables, without increasing the amount of arable land used by agriculture	Reducing waste	A shift to proteins that require less land and produce fewer GHGs; meat consumption cannot persist at today's levels; increased reliance on plant-based or alternative proteins such as fungus, algae or insects			
23. Lancet Global Syndemic Commission 2019			promote a plant-based diet and reduce meat consumption among populations, which represents a double-duty action to reduce obesity, heart disease, and diet-related cancers, as well as reduce methane production from agricultural livestock	Health resilience and adaptation; Health co-benefits of climate change resilience and mitigation	Strengthen civil society engagement; Strengthen accountability systems; Creating sustainable and health-promoting business models for the 21st century	Join up the silos of thinking and action to create platforms to work collaboratively on common systemic drivers and double-duty or triple-duty actions
24. Springmann et al. 2018	cropland and bluewater use are best addressed by improvements in technologies and management that close yield gaps and increase water-use efficiency; improvements in technologies and management that increase use efficiencies for nitrogen and recycling rates for phosphorus	reductions in food loss and waste	dietary changes towards healthier, more plant-based diets			a synergistic combination of measures will be needed to sufficiently mitigate the projected increase in environmental pressures