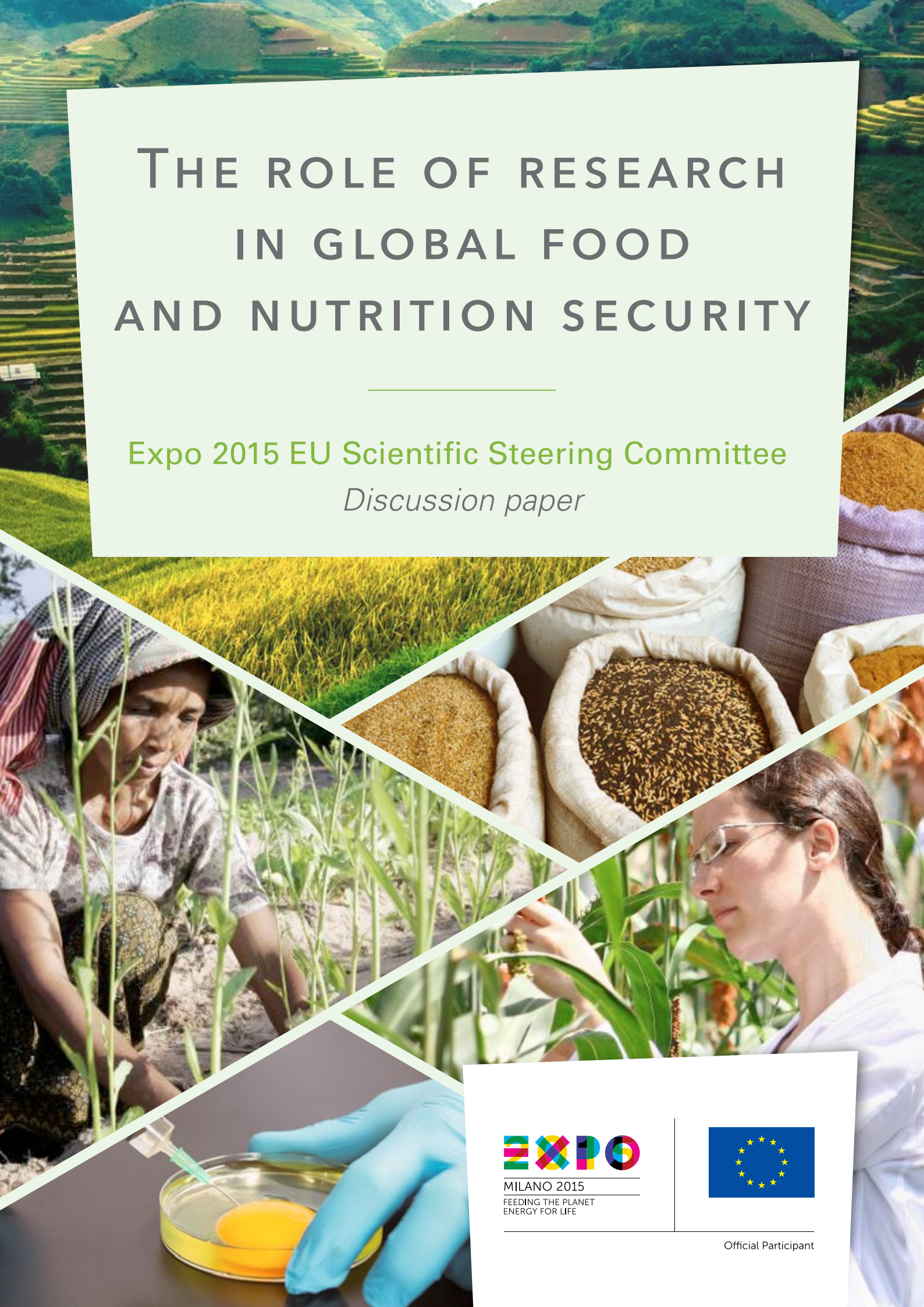

The role of research in global food and nutrition security

Expo 2015 EU Scientific Steering Committee

Discussion paper

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FEEDING THE PLANET
ENERGY FOR LIFE

Official Participant

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Foreword

It has been my pleasure to chair the Expo 2015 EU Scientific Steering Committee tasked with producing this discussion paper on *the role of research in global food and nutrition* security as part of its participation at Expo Milano 2015. When I was invited by the European Parliament and European Commission to lead the work of this committee I gladly accepted.

The issue of food and nutrition security is one that affects us all. We must look to innovative solutions to increase food production if we are to feed a growing world population healthily and sustainably. European research has a key role to play in unlocking the potential of agriculture and in enabling those in developing countries to escape poverty.

The steering committee has prepared a clear cut and realistic research agenda focused on where the EU can add most value in addressing the production of, access to and consumption of food. We have also tried to address structural issues related to new knowledge and the transfer of knowledge into use. Economic, public and environmental health have all been considered in the context of this discussion paper as we looked at seven main themes where research could be better utilised to ensure food and nutrition security. We have chosen to use the term food and nutrition security throughout our paper as the issues at stake are so much more complex than ensuring availability, access and stability of calories. The EU has already demonstrated its commitment to turn the tide against undernutrition; however, we have a political and moral responsibility to go further, and this may include encouraging healthy eating patterns to avoid diseases associated with overconsumption of calories coupled with low levels of physical activity.

The drafting of this discussion paper was guided by 11 scientific experts alongside five stakeholder participants and advisors of international repute (see annex I). Throughout the process we have kept one goal always in mind, to draw on the crucial role that research can play in the fight against world hunger and overcoming the challenges associated with ensuring food and nutrition security for all.

The present discussion document gives an overview of where European research can add the most value in relation to tackling food and nutrition security challenges and points to areas where we can expand our research potential. Moreover, it highlights the need to develop a governance structure that will allow sharing of best practices and facilitate the transfer of knowledge and innovation to feed the planet sustainably. It should stimulate a global discussion with stakeholders and the general public, ultimately shaping a legacy for Expo 2015.

Finally, I would like to thank all members of the steering committee, as well as EU Expo Commissioner General, David Wilkinson and his staff at the Joint Research Centre (JRC) who have facilitated this project.

Mr Franz Fischler,
Chair of the Expo 2015 EU Scientific
Steering Committee

Steering Committee for the EU scientific programme for Expo 2015

The Steering Committee of the EU scientific programme for Expo 2015 is a joint initiative of the European Commission and the European Parliament and was launched on 21st March 2014.

Given the political importance of the Expo theme, this Committee was set up in order to ensure that the European Union takes the opportunity offered by the platform of Expo 2015 "to establish its role as a key player in this global debate […] and to work towards fruitful collaboration on these matters with other stakeholders, both public and private" (COM(2013) 255 final).

Franz Fischler was nominated as its chair by former Commissioner Maire Geoghegan-Quinn. Its eleven scientific experts have been selected in a broad and comprehensive process by a selection panel, which was nominated by the EU Expo Commissioner General, David Wilkinson in December 2013. The three members of the panel were Pamela Byrne, Pier Sandro Cocconcelli and Harry Kuiper. Based on the agreement between the chair and the EU Expo Commissioner General the committee also includes stakeholder participants from the United Nations, OECD, the private sector and civil society. Subject to the agreement with the chairman the committee can invite external experts to specific meetings whenever necessary.

The secretariat of the steering committee is provided by the EU Expo 2015 Taskforce and based in the Joint Research Centre, the European Commission's in-house science service. Working in close cooperation with policy Directorates-General the JRC's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

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Table of contents

Executive Summary **2**

Introduction **4**

What is food and nutrition security? 5

Why is food such an issue? Demand and supply under increased pressure 5

Finding solutions to global food and nutrition security: the need for research and innovation 7

Where are the research challenges in addressing food and nutrition security? **8**

Theme A: Improve public health through nutrition – healthy and sustainable consumption 9

Theme B: Increase food safety and quality 10

Theme C: Reduce losses and waste – more efficient food chain 12

Theme D: Manage the land for all ecosystem services – sustainable rural development 13

Theme E: Increase agricultural outputs sustainably – sustainable intensification 14

Theme F: Understand food markets in an increasingly globalised food system 17

Theme G: Increase equity in the food system 18

Structural issues that apply across all themes **20**

Setting the agenda: foresighting and futures' research 21

Addressing multiple goals: stimulating interdisciplinary and strategic research and action 21

Investing in and aligning research 22

Transferring research knowledge into innovation and practice 23

Education and communication to the public 23

Where can the EU add most value? **24**

Executive Summary

Feeding the Planet, Energy for Life is the theme of the 99th World Expo in Milan in 2015. To elaborate this theme the EU established a scientific steering committee to advise on the challenges of global food and nutrition security. The Expo 2015 EU Scientific Steering Committee, established to provide expert advice on the Expo's theme, has produced this "discussion paper" to launch a debate, to foster cross-disciplinary exchange, define research questions, and identify the EU's role in addressing global food and nutrition security.

Currently, 805 million[1] people are chronically hungry in the developing world[2]. Around two billion more people suffer from micronutrient deficiencies. Lack of adequate nutrition is primarily due to lack of access to food and this is in most cases due to relative or absolute poverty[3]. Furthermore, limited access to food and rapid food price inflation can be a cause of civil unrest and drive human migration. Paradoxically, at the same time as billions suffer food insecurity more than two billion people are overweight or obese as a consequence of over-consumption of calories and lack of physical activity. This progressively increases personal, public-health and environmental costs and thereby increases the pressure on the global food and health systems[4]. Food and nutrition security is an issue for all societies.

Historically, global production of food has outpaced demand. However, this "outpacing" is now slowing due to both supply and demand-issues. People demand more and diverse food, and on the supply-side, historic yield growth has slowed or plateaued in recent years. In addition, there is increased competition for land, water and other natural resources; climate change is also threatening production growth in many areas. Additionally, reducing the environmental impact of agriculture, including greenhouse gas emissions, may in future require new and innovative farming methods.

Where are the research & innovation challenges?

There is unlikely to be any single or easy solution to tackle food and nutrition security fully[5] and many of the challenges of ensuring global food and nutrition security cannot be adequately addressed without the participation of the research community. In the past, the focus has been on increasing food production to meet a growing demand but recently more emphasis has been put on the fact that up to a third of the world's food production is lost or wasted[6]. Moreover, food consumption patterns in combination with sedentary lifestyles can turn into significant and rising burdens on public health[7]. Thus, it is of paramount importance to take a "food systems" view[8].

This requires equal attention on improving agricultural and fisheries' productivity, reducing the negative environmental impacts of production (including reducing emis-sions of greenhouse gasses), reducing waste at all stages in the food chain and in helping citizens eat more healthily. The EU has excellent intellectual resources which can be brought to bear to mitigate the growing risks of global food and nutrition insecurity, with the desired outcomes of improving economic growth, public health and the environment. To address these broad challenges both new knowledge

and enhanced movement of knowledge into use is needed. The committee has identified research challenges across seven broad themes and these are discussed in detail in the paper, along with many specific examples of the associated research questions.

Cross-cutting issues for creating and using knowledge

There are a number of cross-cutting structural issues to enhance the utility of knowledge-generation within the EU that are interlinked to make a "virtuous spiral". Indeed, initially, strategic analysis of the future ("foresighting") should set the research needs via a systems approach. Research undertaken, by Member States, by the EU and globally, can then generate interdisciplinary knowledge to address the needs of the "multiple bottom lines" for economic, public and environmental "health". The research effort across different countries also needs aligning to ensure its complementarity. The knowledge generated then needs to be utilised to create technological and social innovation (including via education). Innovation then creates, in turn, social and economic change. This, coupled with global development and environmental change over time, then requires the forecasting to be updated.

Where can the EU add most value?

The EU is a unique entity which coordinates research, policy and practice that affects a large number of countries. It hosts a vast human capital of researchers, with significant amounts of world-leading expertise. Many of the issues raised by the food and nutrition security challenge are inherently interdisciplinary, multi-sectoral and culturally-entrenched. The EU already has a strong track record of coordination between research providers, across countries, and research users across policy domains.

The EU therefore has an important role to play in delivering research against the challenges, but also in showing international leadership in research and innovation for economic and societal benefits by generating sustainable economic growth and employment and for enhancing health and well-being.

There is scope for the further development of mechanisms for enhancing research-into-use, via:

- Research prioritisation to ensure that knowledge is generated across the complex global agri-food system with the highest positive impact for economic, public and environmental health.
- Developing instruments for aligning complex research challenges across multiple societal needs and across space (within and between member states and beyond).
- Promoting a sophisticated and inclusive innovation culture building on European Innovation Partnerships, within the EU and beyond (e.g. in Africa); particularly via facilitating a sustainable bioeconomy and sharing related science and institutional knowledge internationally.
- Improvement of communication and knowledge exchange that is inclusive and respectful of cultural complexity.
- Developing models of governance for delivering sustainable agriculture and nutrition from local to supra-national scales.

Introduction

The next, and 99th, Universal Exposition will take place in 2015 in Milan on the theme "*Feeding the Planet, Energy for Life*". Since 1851, "Expos" have been major international events serving as a forum for dialogue between governments and institutions, and also acting as an opportunity for knowledge exchange with the public on the Expo theme. "*Feeding the Planet*" is one of the most pressing challenges of our time, and is of prime importance for the EU. Many EU policy areas are related to it: from agriculture to development, from food safety and consumer health to environmental protection, from industry to research and innovation; and the EU has an important role to play in providing solutions.

Expo 2015 coincides with the target year of the Millennium Development Goals, the launching of the Sustainable Development Goals and the midpoint of Europe's 2020 Strategy. Expo 2015 organisers' initial strategy document aimed to highlight the importance of social and political discussion: "*The theme of* Feeding the Planet, Energy for Life *impacts [on] the strategic decisions governments [will] be making in forthcoming decades, and… the everyday experience of every… human being*". Expo provides an opportunity to communicate with citizens, and also a platform to foster global research and policy development through international conferences, workshops, exchanges of best practices and joint declarations on actions. The goal is for the Expo 2015 theme to have a lasting legacy by stimulating a policy debate among the 148 participating countries and international organisations.

The EU is an important stakeholder in the global debate on how best to achieve food and nutrition security. Research within Europe, and alignment of Europe's research (and funding) with other countries has a significant role to play to address food and nutrition security in Europe and globally. A Steering Committee was established to provide expert advice on Expo's theme. The Steering Committee's role was to (a) give guidance on the draft programme of conferences, work-shops and online consultation for Expo 2015, and (b) provide this paper highlighting priorities for research, development and innovation on the theme of global food and nutrition security.

This paper should stimulate discussion with stakeholders and the general public and ultimately contribute to the EU's legacy from the Expo. It is a "think piece" suggesting a strategy to address the challenges spanning the production of, access to, and consumption of food. The paper does not make recommendations for policy, rather it aims to prompt discussion of where research and innovation can contribute most to solving the issues, including providing underpinning evidence for policy development.

What is food and nutrition security?

Food security[9], as defined by the Food and Agriculture Organization (FAO), occurs when *all people, all of the time, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life*[10]. Clearly, with an estimated 805 million[11] who are chronically hungry in the developing world now[12], and 165 million children who are stunted and will carry the burden of this through their lives[13], we are far from this, globally. A further two billion individuals suffer from iron deficiency or other micronutrient deficiencies (vitamins, minerals, trace elements)[14] highlighting the importance of the need for nutrients beyond calories. For billions of people, the problems of gaining adequate nutrition and calories are primarily due to lack of access to food. For most, this is due to poverty[15]. Beyond impacts on health, lack of access to food can destabilise communities especially in periods of rapid food price inflation[16]. Food and nutrition insecurity can also act as a driver for changing patterns of human migration, including transnationally[17].

The developed world also has food insecure people: growing income inequality means that the number of those struggling to feed their family is increasing. Across the EU some 50 million people face material deprivation, with 18 million receiving food aid in 2010[18]. Malnutrition is not just a problem of under-consumption[19]: more than a third of all adults are overweight or obese[20]; leading to personal, public-health and environmental costs and adding more pressure to the global food system[21]. We therefore include discussion of the research challenges that arise from a high caloric intake and inadequate physical exercise with the need to encourage healthy and sustainable eating patterns, and a reduction in waste along the food chain.

The paper gives a big picture overview of the growing global demand for food, and the supply-side constraints. Then the research and knowledge needs are discussed, grouped into seven broad themes, focussing on where research within the EU can add most value in addressing the production of, access to and consumption of food. Finally structural issues are examined to do with knowledge generation and use.

Why is food such an issue? Demand and supply under increased pressure

Historically, global growth in production of food has matched or slightly outpaced growth in consumption, as indicated by the downward trend in real food prices in the 20th Century. However, this "outpacing" has slowed due to changes in both demand and supply.

On the demand side, demand for food and other agricultural[22] outputs (especially biofuels) is growing rapidly. By the middle of the century, there will be about a third more people on the planet. At the moment, about two billion people are in the global middle class income bracket of $10-100 per day and this number is expected to rise by three billion by 2030; the bulk of this increase will be in the Asia-Pacific region[23]. As people get richer, their diets change,

typically eating both more and differently. Demand projections to mid-century suggest a need for 60-110%[24] more food. This is primarily driven by growing demand for, and intensification of, livestock production (crops for feed currently represent 53% of global plant protein production, and 36% of calorie production, enough to supply calories for four billion people)[25].

On the supply-side, increasing world food production to meet growing demand faces three main challenges. First, the yields per hectare of the main agricultural crops are currently increasing at rates that are insufficient to match long-term demand without using significantly more land[26]. Innovation is therefore needed to raise yields in ways that do not undermine sustainability.

Second, competition for natural resources is growing. Productive agricultural land is increasingly used for producing biofuels and other non-food products, as well as being converted into urban infrastructure; some is also lost due to degradation of soils[27] and desertification. Deforestation to create further land for agriculture is undesirable due to the social and environmental costs associated (e.g. biodiversity loss, greenhouse gas emissions). Water for agriculture currently accounts for 70% of abstraction from rivers and groundwater globally[28]. A recent analysis suggests that to meet demand, and assuming yield gaps are reduced through research and technology, 56% more water for irrigation would be required by 2050[29]. In many areas, even with efficiency gains, such increased water demand may not be attainable. Increasing pressures on marine resources are leading to the depletion of fish stocks, threatening over 500 million people[30] who depend, directly or indirectly, on fisheries and aquaculture for their livelihoods. Furthermore, fish is paramount to food and nutrition security as it provides a significant component of animal protein for over four billion people[31] and at least 50% of animal protein and micronutrients for 400 million people in the poorest countries. A parallel development is that aquaculture has been the fastest growing food related activity but it also brings its own challenges, akin to those of agriculture (i.e. space needs, inputs and pollution). Increasing competition for resources applies not just to production, but also across the food-chain: for example, food processing accounts for 5-10% of industrial water use, and 17% of aluminium use is for packaging, the majority for food and drink[32].

Third, the climate, and therefore the weather, is changing. Estimates of the impact of future climate change – on today's farming systems – vary according to the methods used, the crop, and the location. For the period 2030-2049, about 10% of projections are for yield gains of more than 10% relatively to the late 20th century; but about 10% of projections indicate yield losses of more than 25%, mainly in the low latitudes[33]. Such estimates highlight the need for agricultural adaptation (including changing genetics of crop plants) to avoid yield loss[34]. In addition to changes in average yields, there is considerable uncertainty about the impacts of changing patterns of extreme-weather on production. Current projections are for yields to become more variable, with year-on-year variability perhaps increasing by 50%[35] by 2050. To exemplify the potential impact of climate change, a recent study on maize in France concluded that, over the next two decades, yields would need to increase by more than 12% simply to offset the increasing frequency of very hot days[36]. Climate change also affects oceans and aquatic systems for example through rising sea levels, acidification, warming of waters and storms. Although fishing activities may impact stocks and ecosystem more than climate change, weakened fishery resources are more vulnerable to collapse due to climate change[37]. In addition to the need to adapt to climate change, globally agriculture accounts for between a quarter and a third

of greenhouse gas emissions[38]; mitigation of climate change via reducing emissions is itself a considerable challenge and may in future require farming in different ways.

In conclusion, demand for food is growing and supply growth faces a range of significant constraints. These challenges play out in an increasingly globalised world, where international trade in food is growing exponentially[39]. Trade creates connections between spatially separated parts of the world, such that production (and its impacts) is separated from consumption, it allows more efficient allocation of resoures and shares the burden of supply shocks reducing price volatility.

Finding solutions to global food and nutrition security: the need for research and innovation

Many of the issues associated with meeting the demand for food in the face of climate change, potentially on less land, with less water, and lower environmental impacts require research and innovation. There is unlikely to be any single or easy solution to tackle food and nutrition security fully[40]. In the past the focus has been on increasing food production to meet growing demand but more recently it has also been emphasised that up to a third of the world's food production is lost or wasted[41]. Moreover, increasingly food consumption patterns in combination with sedentary lifestyles turn into significant and rising burdens on public health[42]. Thus, it is necessary to take a "food systems" view[43] giving equal attention to improving agricultural and fisheries' productivity, reducing the negative environmental impacts of production, reducing waste at all stages in the food chain and helping citizens of all countries eat more healthily. The EU has excellent intellectual resources for research and innovation which can mitigate the risks associated with global food insecurity and lead to simultaneously improving economic growth, public health and the environment. An important strategic innovation addressing these issues is the concept of the knowledge-based "bioeconomy", pioneered by the EU, and Germany in recent years, and subsequently adopted by many other countries.[44] Agriculture is increasingly considered as a key part of the bioeconomy, i.e. the production, transformation and utilisation of bio-based resources and materials.

The agri-food system – and its impacts on the environment and public health – is inherently complex. Whilst research may be able to abolish or resolve some of the inherent trade-offs (e.g. between production of food and environmental protection), many will remain. A trade-off implies the need for a societal choice on how best to balance ("optimise") between the different ecosystem services and whilst research can help identify the issues, and underpin good policy by providing knowledge, it cannot itself determine solutions to trade-offs.

Where are the research challenges in addressing food and nutrition security?

To address the global food and nutrition security challenge both new knowledge and enhanced movement of knowledge into use are needed. Informed by a range of horizon scanning, foresight and research prioritisation exercises[45] including those underpinning the development of the Horizon2020 programme[46], the committee identified prime research areas which are grouped into 7 themes *(Figure 1)*.

Figure 1

A number of generic issues apply across the themes. Climate change will have profound effects not just on production, but may also impact on food safety and spoilage, international trade via weather-related disruptions and interact with nutrition to affect health. Climate change mitigation may also require changing practice along the food chain which may affect production and transport. Many of the areas highlight "wicked problems", where there are trade-offs between social objectives; navigating these to produce an equitable outcome can be very difficult. Delivering outcomes contributing to the three goals of simultaneously improving the economy, public health and environment may require social or institutional reform, not just research. There is thus a broad governance task of making and implementing appropriate societal choices to optimise the agri-food system.

The Expo 2015 EU Scientific Steering Committee describes the themes below and gives exemplar research questions and innovation needs which emerge from them. All themes are important, and all have to be tackled. First, consumption patterns and food safety and quality themes are discussed to reflect that these are areas where we think Europe has greatest need and demonstrates examples of best practice respectively that could lead the way to more sustainable food systems. These are followed by waste-reduction, resource management and sustainable agriculture themes, indicating areas high on the policy agenda of the EU where we consider Europe can provide examples for others to follow. The description ends with the themes on trade and global equity, as these may require concerted global action.

Theme A
Improve public health through nutrition: healthy and sustainable consumption

Globally, access to more and better food has increased in recent history, and a functioning agri-food system that provides a diversity of produce, cheaply, at all times, is something many of us take for granted. The life expectancy of European citizens is steadily increasing[47], and good nutrition and agri-food processes are likely to have contributed to this. However, there remain adverse nutritional outcomes from the agri-food system. For the global poor, access to sufficient food for a healthy diet remains a daily struggle, with a significant proportion of the global population suffering from chronic hunger and nutrient deficiency, and with poor maternal nutrition leading to lifelong consequences for children. Despite this, the major causes of death and disability worldwide are now non-communicable diseases (NCDs), such as heart disease and diabetes[48]. Topping the risk factors for NCDs are dietary factors. In 2013, an estimated 32 million adults aged 20-79 in the EU had diabetes, and the health expenditure allocated to treat and prevent this disease and its complications was estimated to be in the order of 100 billion euros[49] In addition, unhealthy diet is linked to increased cancer risk and heart disease. Across the world obesity is increasing. In the EU, about 20% of people are obese (~150m people)[50].

With diet-related non-communicable diseases becoming a global driver of ill health, encouraging healthier diets, coupled with the promotion of more active lifestyles and sport is a positive strategy for enhancing public health. Informing consumers about the implications of their food choices will also benefit the environment. There are therefore increasing needs to recognise that agriculture, food, nutrition and health are intertwined[51]: what is grown, its nutritional composition, and how it is consumed are all important drivers of public health in rich and poor nations alike.

Enhancing the nutritional composition of agricultural production and the formulation of foods to benefit public health present research challenges. For the poorest, this may be about production of sufficient nutrition (Theme E), empowerment (Theme G) and access to markets (Theme F). In the developing world economic growth is creating dietary transitions from subsistence-diets to more westernised diets. How can research help underpin transitions which are positive for health? In the developed world, perhaps even more important is the understanding of how to promote wise consumption decisions and therefore, at a population level, eating sustainable healthy diets.

Exemplar research areas

- Better understanding of the specific nutritional requirements of different demographic groups (e.g. the aged) or different genotypes is required. What is the role for "personalised nutrition" and how it can be achieved?
- Enhancing the ability to provide healthy, safe and sustainable food for those on low incomes.
- Understanding consumer behaviour better to find ways of creating changes in food consumption that reduce the public health burden and environmental costs of farming: understanding and promoting "sustainable nutrition".
- Given economic growth, and developing countries' associated dietary transitions, defining interventions that most effectively reduce (or prevent) the twin public-health burdens of malnourishment through under- and over-consumption.
- Enhancing the nutritional quality of food through identification, and promotion of, alternative farming systems, including more diversified ones, or different crops.
- Developing biofortification, fortification and reformulation of food for health outcomes whilst ensuring public acceptance of this.
- Better understanding is needed of the human metabolic system and how it interacts with diet, including the role of the gut microbiome in healthy and diseased states.

Theme B
Increase food safety and quality

In addition to nutrition for good health, globally consumers need food that is safe to eat as well as water that is safe to drink. Increasing food safety requires attention throughout the food chain from "plough to plate". There are risks associated with chemical contamination of products (e.g. some use of pesticides), or contaminated in-gredients (sometimes substituted for economic reasons), spoilage, microbial contamination, and adulteration (as a form of

fraud, or even bioterrorism). Identifying risks and mitigation actions can take many forms, technological, regulatory or social (e.g. better understanding of food storage and labelling).

Food safety requires transparent supply chains, and labels that consumers trust to ensure authentic, unadulterated and uncontaminated food. Food safety is also implicit in themes A and C: healthy diets and managing food waste. Ensuring safety requires significant regulation and the development of food preparation, transport and logistics, which are safe and transparent, coupled with enhanced testing for adulteration or contamination. Safety also requires better education about risks.

A related area concerns certification and labelling schemes to promote quality and other attributes. The EU's "Geographical Indication" scheme recognises the geographical origin of certain foods, to promote attributes of traditional production systems. Organic agriculture is also supported to foster diversification of food production and to reduce its environmental impact. Such schemes allow traditional local expertise to participate in global markets and may function as social protection. Many important research questions remain about the role that such schemes have for balancing consumers' versus producers' interests, and the role they play in international trade.

Exemplar research areas

- Enhancing production, storage, processing and logistics, especially in the developing world to mitigate the contamination risks of food or water by, for example, microbial contaminants (including from poor sewerage, or aflatoxins arising from poor storage) or improper use of pesticides.
- Developing smarter food production, processing and logistics to limit the potential for adulteration or contamination of food (including food fraud and bio-terrorism).
- Developing sensors and sensing systems, for laboratory and field, to ensure safety and traceability of food during transport, processing and retailing. Improving scientific (e.g. genetic fingerprinting) and legal tools to combat counterfeiting and enhance traceability.
- Improving our risk assessment and management strategies for complex whole foods of microbial, plant or animal origin (including identifying allergenicity risks).
- Innovating food safety regulations (and labels) that minimises waste and enhances safety by promoting consumer understanding of risks.
- Enhancing research in order to promote harmonisation of labelling and information systems, including the development of communication tools for ethical (eg. animal welfare), environmental and social attributes of food products[52].
- Enhancing organisational and institutional cooperation to promote best practices in building and managing certification systems in developing countries.
- Promoting social research to better understand consumer attitudes to "values" (quality, environmental standards) rather than simply the value (economic price). This understanding will enable consumers to easily make informed choices in light of changing food products in terms of composition, origin and health and en-vironmental impacts.
- Investigating which "quality" regulations are important for society and which are primarily of interest to producers and may, in specific cases, negatively affect society.

Theme C
Reduce losses and waste: more efficient food chain

Significant agricultural production is lost or wasted from the farm to the home[53]. In developing countries, food losses result from wide-ranging managerial and technical limitations in harvesting techniques, storage, transportation, processing, cooling facilities, infrastructure, packaging and marketing systems. Across the EU, an estimated 90 million tonnes of food is wasted[54]; for example, in 2012, Sweden wasted 127 kg of food per person. This estimate does not include the food wasted in the production phase (agriculture and fishing) and the inevitable food waste from the food processing industry. Of this amount, 81 kg per person was generated in households[55]. In sum, waste produced by EU and North America is equivalent to the total food production of sub-Saharan Africa. Little reliable data exists for on-farm losses in the EU but they may be significant[56], due to weather, outgrading and "insurance" production for supermarket contracts.

Finding ways to minimise loss and wastage of food (as well as energy and nutrients) through the supply chain, from "farm to flush" will need many technologies such as longer-range weather forecasting for agricultural planning and demand forecasting, smarter packaging and supply chain logistics, changed genetics for improved storage, recycling technologies. Changes in consumers' knowledge, attitudes and food cultures may also be as important. Whilst we focus on food loss and waste, the broader challenge exists of increasing efficiency and reducing waste across agri-food supply chains. Furthermore, where waste is unavoidable (including human waste) there is a need to increase recycling of the nutrient content, especially phosphate and nitrate, organic matter and also energy (e.g. via anaerobic digestion).

Exemplar research areas

- Developing better knowledge about where food is lost and wasted throughout supply chains, and therefore where the leverage-points are for action, and understanding the costs-and-benefits associated with them. This applies to local and global food-chains, and both in the developed and developing worlds.
- Improving genetics for enhanced storage (whilst maintaining taste, quality and safety).
- Across the world, creating smarter logistics, packaging, storage and supply chains to reduce spoilage, recognising the differences in developing and developed worlds' supply chains.
- Enhancing public understanding of quality assurance (sell by/best before/expiry) dates to reduce waste as well as other interventions in the home (meal planning, smart fridges).
- Improving prediction to align demand and supply (e.g. seasonal weather forecasting) to minimise "insurance" production that goes to waste if supply and demand are mismatched.
- Developing recycling technologies to optimise recovery of energy, organic matter and nutrients from waste and ensure its safety for reuse.
- Developing innovative products from food industry residues.
- Increasing innovations to improve efficiency and reduce any form of waste (e.g. water, energy, aluminium and other packaging) across supply chains.

Theme D
Manage the land for all ecosystem services: sustainable rural development

Agricultural landscapes provide a wide range of goods and services to society. These "environmental services[57]" include provision of food, and also fuels, fibre and clean water, and "non-provisioning" services, such as the cultural value of the landscape. Agricultural landscapes provide habitats for biodiversity that aids production (such as pollinators, natural pest control and soil biodiversity) but also culturally important biodiversity exemplified by flowers, butterflies and birds. Agricultural landscapes also affect water-flow and flood-risk downstream, and provide important recrea-tion and amenity use, improving health and well-being. They can sequester carbon. They support rural livelihoods and have cultural value. Agricultural landscapes thus have important heritage protection roles (for cuisine, dress, customs, language, architecture). Rural recreation and tourism and the non-food provisioning services are of massive economic, social and cultural importance in Europe; they are an important part of what EU rural development policy aims to encourage and protect. Agricultural land creates a nexus between many different goods and services that we require.

Agricultural management (Theme E) plays a part in maintaining the range of environmental services at local as well as at larger scale. It does this through appropriate use of inputs, tillage, and management of non-cropped areas providing habitat for biodiversity and protection of water-courses. However, some integrated land-use planning may be needed to ensure that agriculture, rural development, and wider ecosystem service provision are maintained in a place-appropriate way. Agricultural landscapes also interface with estuarine and coastal ecosystems so land-based agriculture may affect environmental services in fresh and salt water. In the marine environment for both wild-caught fisheries and aquaculture, similar issues apply around maintaining environmental services at a large scale.

Whilst this theme focuses on balancing land use to produce all that society requires, these issues also arise at global scale. Globally, some areas of land have higher agricultural potential, whereas others may support globally significant environmental services (e.g. tropical rainforests). What mechanisms of global analysis and governance can apply to balance global land uses for food versus other important services and ensure economic equity and sustainability?

Exemplar research areas

- Better understanding of the "earth system" is needed and how it will respond to increased atmospheric carbon dioxide, including the impacts on climate, weather and yield potential.
- Enhancing research on which to build decision-support tools for optimising land use, which will maintain a range of environmental services (including production of food, fuel or fibre), specific to place and at appropriate scale. This includes better knowledge of the link between small-scale practices (at the field scale) and outcomes, such as on water quality or biodiversity, at the landscape, or catchment scale. This requires understanding, and managing, the potential conflicts between different land uses (and their users) and their impact of different services.

Such decision-support tools may be needed at the landscape (or community) scale as well as at bigger scales sub- to supra-national.

- If decision-support tools, highlighted in the bullet above, facilitate our actions, the next step involves investigating how to implement these decisions at a community/country/regional level. This may especially be the case in small-scale farming systems in marginal areas, and, in the tropical world, ways of incentivising forest preservation rather than deforestation. The challenges are (a) to identify how to reward the ecosystem services these areas can supply; and (b) to discuss the farming structures needed to deliver this and the restructuring processes to get there. This broadly includes "social farming" in the potential for using small-scale agriculture to provide social or educational care services for the vulnerable.
- Identifying the existence of thresholds which, if crossed, cause environmental services, including food provisioning, to decline rapidly (local- and planetary boundaries). Develop ways of assessing the trajectory towards them, and predicting when they may be crossed. These questions should be investigated at all scales.
- Developing a stronger, publically available, evidence-base to underpin the sustainable implementation of EU policy instruments such as the Common Agricultural Policy, Rural Development and Structural Policy or Water Framework Directive.

Theme E
Increase agricultural outputs sustainably: sustainable intensification

Given that little, if any extra land is available for agriculture, there is a need to increase yields from the existing agricultural land area whilst simultaneously reducing the environmental impact. This is "sustainable intensification"[58]. These issues about productivity and sustainability apply as much to fisheries and aquaculture as agriculture. Sustainability is an essential requirement, without which there is the potential to cross local- and planetary boundaries, beyond which agricultural performance may decline. In addition, sustainability encompasses the need for maintaining livelihoods, as well as environmental services for wider societal good (Theme D). One route towards sustainable intensification may come from systems' analysis of ecological systems (sometimes called "agro-ecology"[59]) to drive ecological intensification. A related route comes from organic agriculture, which has reduced environmental impacts compared to conventional farming, but requires more research to close improve productivity. In addition, as highlighted above, the important societal outcomes from the agri-food system include health: so when considering "yields", the nutritional quality and food safety (themes A and B) are as important as the amount of food.

As places may differ significantly in many characteristics, one-size-fits-all solutions do not universally apply. Opportunities exist for developing different approaches for different locations to provide overall yield gains in a sustainable way.

For any farmed plant or animal its phenotype (and thus its yield), depends on a complex interaction between its genes, the local environment and the way it is farmed. Better understanding the gene x environment x management (GxExM) interaction is needed to support agriculture and sustainable management appropriate to location, and in relationship to climate change, "climate smart agriculture"[60].

Genetic improvement of crops and livestock (including fish for aquaculture), whether for the quality or quantity of yield, or resistance to pests, heat or drought, requires the utilisation of modern biotechnology (which spans a continuum between conventional breeding and genetic modification). Modern biotechnology, along with related emerging technologies aimed at genetic adjustment and improvement, such as synthetic biology, and other technologies that may be used in agricultural and food production processes, such as nanotechnology, require significant dialogue with society to ensure legitimacy and the minimisation of risks (whether environmental, health, economic or livelihoods). Specifically within the livestock sector, sustainable intensification also requires consideration of a range of welfare issues.

Agricultural land management sits within wider land uses (Theme D) and agriculture's impacts affect these. Improving sustainability at the farm scale requires more than improvement in efficiency. Sustainability requires better management of inputs, including their potential substitution, to reduce their effects on the wider environment. However, the impacts of a management practice may depend on the location, so operisationalising "sustainable intensification" in a place-appropriate way is a subject of significant research, including developing appropriate measurement systems and understanding of trade-offs between yields and environmental impacts. And, of course, there are broader issues of social sustainability (themes D and G) which may also trade-off against economic sustainability (which typically depends on the volume of yield) or environmental impacts. Similar issues apply in managing the sustainability of aquaculture and managed fisheries.

Exemplar research areas

- Developing metrics for measuring sustainability and resilience, as well as impacts upon ecosystem services and natural capital.
- Developing greater understanding of the potential impact of climate change on production at a variety of spatial scales, and including understanding of the uncertainty of the estimates.
- Developing precision crop and livestock agriculture; including sensing at animal/plant, field and landscape levels, and their engineering applications (including robotics) and decision-support tools. For livestock this includes formulating food and manipulating the gut microbiome for positive outcomes for growth, methane reduction and efficiency, and developing individual health surveillance to avoid prophylactic antimicrobial therapy.
- Developing better integrated soil management for nutrients, carbon-storage, water quality and retention to ensure long-term sustainability.
- Developing or enhancing alternative farming systems:
    - Enhancing the development of approaches to improve re-use and recycling to create "circular" agricultural systems. This includes the recovery and recycling of phosphate, nitrates, potash and organic matter from the nutrient surplus areas (urban areas and areas of intensive livestock production) to nutrient deficit areas, typically arable areas. Research is needed on how to manage this technically, institutionally, for food safety and culturally (such as social

acceptance of treated sewage sludge for food crops).

- Developing urban and peri-urban farming systems, including vertical farming, to provision cities.
- Utilising agro-forestry or permaculture to enhance both carbon storage and production[61].
- Utilising ecological processes and interactions to increase resilience. For example, soil regeneration; enhancing mycorrhizal associations and natural pest control to reduce inputs; or the development of long-term carbon sinks through intercropping with, for example, the Iroko tree which builds carbonate layers in soil[62].
- The goal of "sustainable nutrition" (Figure 1, Theme A) implies changes in diets and therefore agricultural production. Horticulture places different requirements on soils, water, management, as well as requiring different genetics. What crops should be developed and where? Investigating the structural changes that can promote changes in farming systems that are sustainable environmentally and for livelihoods of rural communities is needed.

- Utilising new sources of protein (such as algae, plants, insects, or from stem cells) for feed and food production. Improving aquaculture systems for delivery of protein with high-welfare and low environmental impact.
- Improving genetics of crops and livestock is necessary to tackle many issues of increasing yields, and their quality, whilst also coping with other challenges. For example:
  - Developing genetics for the changing climate (whether more extremes of heat, drought or rainfall, or via resilience to variability to maintain yield stability), and for specific places (to optimise the GxExM).
  - Given increasing competition for (and societally-led regulation of) inputs, improving resource-use-efficiency (nutrients, pesticides, water etc) will be important, as well as development of agronomic practice to this end.
  - The concentration on a small number of agricultural products, over larger land areas, creates a risk in the homogeneity of production and consumption at a global scale[63].
    - New pests and pathogens are likely to arise due to globalisation and changing climate. Developing new means of breeding for sustainable pest resistance, as well as predicting, and tackling pests, are important areas of endeavour.
    - Developing new crop varieties to reduce risks and enhance nutritional outcomes
  - Improving the nutritional quality of agricultural products including biofortification and new varieties of crop for commercial use. Improving genetics, especially for livestock, and agricultural practices to enhance food safety.
  - Improving photosynthetic efficiency to better harness sunlight by plants and developing perennial and nitrogen fixing crops are long-term innovation challenges.
- Understanding better how to engage with citizens and their attitude to the potential benefits/costs/risks associated with new technologies in agri-food and the environment.
- Better understanding is needed of how to develop governance systems and strategies for sustainable intensification based on participation, precaution and the polluter pays principle.

Theme F
Understand food markets in an increasingly globalised food system

International trade in food has grown faster than production, though it is still a minor share. Traditionally benefits from trade accrue because it allows production to expand where resource endowments confer the greatest advantage. Trading infrastructure, both physical and financial, that facilitates open trade also enables the widest sharing of adjustments to market shocks. Conversely, trade inhibition invariably destabilises markets, widening price volatility. From a European perspective, trade offers the opportunity to export high quality food and drinks and import beverages, agricultural raw materials and feedstuffs less suitable to our temperate climate. As the price gap between the EU and world markets has closed, and also to the extent that Europe may be more immune to climate change impacts than many parts of the rest of the world, markets for EU exports may expand.

There may be some concerns that reliance on global markets for importing significant quantities of food could present increasing risk if production conditions become more variable and the commitment to trade liberalisation falters. So steps are needed to ensure our food system is resilient. Some are concerned that longer, and more complex, supply chains may reduce transparency and increase risk to food authenti-city and safety. Improving the transparency of production, consumption and stocks and understanding the evolution of the global market and how it responds to emerging unprecedented climatic and geo-political shocks are further areas where research is needed.

Exemplar research areas

- Developing tools that help to understand how the global food system may be affected by events not previously experienced like a multiple food system failure (e.g. driven by extreme weather events - El Nino[64]). What would happen to trade, price, access and local land-use decisions?
- Better understanding of how to predict, and manage, risks for safety, authenticity and price stability within logistically efficient and transparent food chains.
- In an era of rising prices, investigating what steps can be taken to lessen the regressive effects on global and local poor.
- Understanding the role of EU production in global food and nutrition security, as well as its potential for economic growth whilst minimising risks.
- Understanding better the risks of globalised and sophisticated just-in-time supply chains and how they relate to local economic growth and its resilience.
- Assessing the robustness and resilience of food, energy, nutrient and other market factors.
- Understanding the balance of economic, environmental and social effects of foreign direct investment in land and other production assets within and outside Europe.

Investigating the integration of ecosystem services and climate needs into trade agreements.

Theme G
Increase equity in the food system

The Sustainable Development Goals (SDGs), to be published in 2015, are overarching goals for sustainable economic development. Many of the SDGs aims have a strong social, ethical or gendered component. In the current draft[65], Goal 1 will be to end poverty everywhere; agriculture has a significant role to play in this for many rural communities in the world. The second goal will be to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture.

As SDGs current Goal 2.3 highlights, one important area is to double the *"incomes of small-scale food producers, particularly women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets, and opportunities for value addition and non-farm employment"* This goal emphasises that access to resources (eg knowledge, finances, inputs) is a major issue for many, and highlights the needs of women. Women are often major care-givers and important for production in many smallholder farming systems, however, they often have poorer access to nutrition, education, income, and to agricultural knowledge and technologies. Furthermore, there are very marked life-course and inter-generational[66] impacts of poor maternal and child nutrition during the first 1000 days of life, so the nutrition of women and children is a key area of focus. When men may have the economic power, how best to implement policy to target women and children requires significant research.

Land tenure is also highlighted in Goal 2.3. This is perhaps particularly important given the recent upwards trends in large scale land acquisitions (LSLA) whereby investors (including governments) seek new land for investment purposes. Many commentators have argued that LSLA have tended to benefit the investors over local communities, displace small farmers and even impact upon food security[67]. Is this necessarily the case, are land rights well and fairly established and traded?

If demand growth exceeds supply growth, it will lead to upward trends in food prices. For rural net producers this can provide welcome income growth. But the landless and urban poor will find their real incomes declining in such circumstances. How will equity of access to food for the poor be ensured? Many analyses suggest that when food prices increase, the poor pay more, trade down and buy less. Cheaper foods are often highly caloric with a poor nutrient composition. Hence in addition to hunger, high food prices can also lead to severe malnutrition and chronic health issues. Ensuring both economic growth and equity is a challenge for policy and governance, and requires significant social science research to inform.

Exemplar research areas

- Identifying culturally sensitive interventions to improve women's nutrition, child nutrition, and women's economic empowerment as food producers, processors and retailers
- Given the importance of malnutrition in the first 1000 days of life, we need to better ensure food and nutrition security for local and global maternal and child health. Identifying what are the best ways to do this for any given socio-cultural situation?

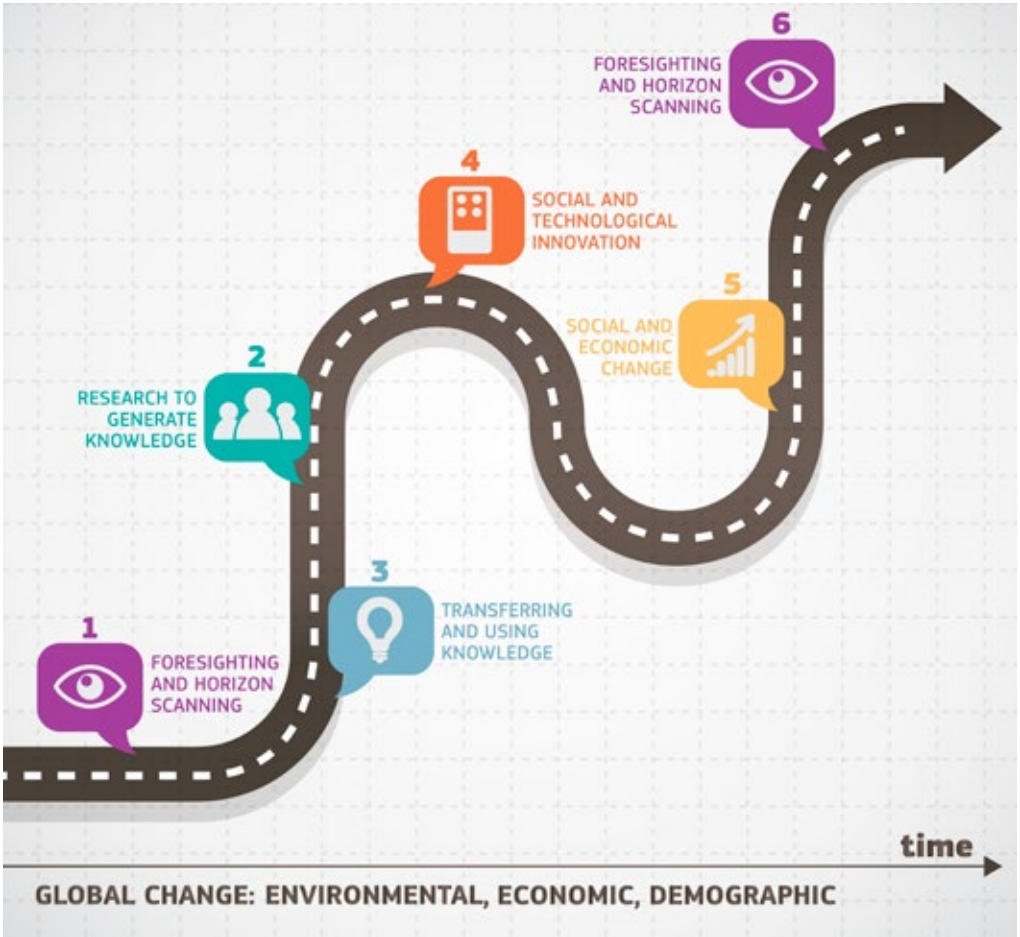
- Access to, and tenure of, agricultural land underpins production and its security in many parts of the world. Investigating how governance institutions can fully take into account the needs of those who have a stake in the land. In the developing world, this primarily concerns models of tenure (and their transformation), in the EU it is also about the public goods coming from agricultural land (themes D and E).
- Minimising costs given the growth of LSLA, and maximising the potential for benefits to investors and traditional inhabitants of the land.
- Strengthening the assessments of the relative importance of small-holding farms compared to larger commercial entities so to ensure a fair place to each of these approaches to farming for the future of agriculture in the developing world.
- Understanding, at country and regional level, the specific causes of food insecurity in order better to develop targeted solutions.
- Food sovereignty implies that citizens should have the right to shape the food system they want, even though the (economic) power often resides in a few large institutions. Identifying to what extent, and in what way, food sovereignty can align with institutional power is needed. Although food sovereignty is often seen as less relevant in the developed world, the current rejection of GM food production by some EU citizens can be seen as an issue of food sovereignty. How best to resolve such issues is an active area of research.
- Developing interventions to enhance access to nutritious food for the EU's poorest.
- Investigating what reduces the vulnerability of subsistence farming systems?

None of these seven themes stands alone. Together, they exemplify the "systems approach" to the agri-food chain. The big challenge is how, appropriate to each region or country, sustainable food systems can be developed, that simultaneously have positive outcomes for human health, environmental health, rural community health and economic growth, and through these achieve global food and nutrition security.

Structural issues that apply across all themes

There are a number of cross-cutting structural issues to enhance the utility of knowledge-generation within the EU. These issues are characterised as being interlinked to make a virtuous spiral *(Figure 2)*. Initially, strategic analysis of the future (foresighting) sets the research needs. Research is then undertaken, by member states, by the EU and globally, to generate knowledge. This research needs to address the triple "bottom lines" for economic, public and environmental health, and therefore has to be interdisciplinary and undertaken within a systems approach. Research effort across different countries should be better aligned to ensure complementarity of efforts.

Figure 2



The knowledge generated then should be utilised by creating technological and social innovation (in part through education and communication). Innovation then, in turn, creates social and economic change. This coupled with global development and environmental change happening through time, then requires the forecasting to be updated. These issues are explored in turn below.

Setting the agenda: foresighting and futures' research

The world is changing very fast given demographic change, population, and economic growth, coupled with climate change and a range of geo-political issues. Strategic research takes time to deliver outcomes, so delivering research to underpin future innovation needs is aided by scoping what these may be. This requires using (and further developing) methodologies for looking ahead, via developing scenarios, foresighting and horizon scanning. This is not in order to predict the future, but to look at plausible futures as a guide to developing either strategies for planning or finding solutions that "fit most scenarios". Such approaches can also help avoid closing down future options if the world ends up not as we imagine it. Given the EU's academic expertise, its cultural and geo-political heterogeneity and strengths in integrating across disciplines and countries, there is considerable scope for further enhancing our world-leading expertise in this area.

Addressing multiple goals: stimulating interdisciplinary and strategic research and action

"Food and nutrition security" can be considered as a "meta-challenge" as it necessarily covers health, production, environment, trade, economics and international development. Finding the right balance across the three areas of economic, environmental and public health requires new ways of thinking. Additionally, the food system is highly dependent on water, energy and land use. These complex interactions are sometimes termed the "nexus" problem. For example, agriculture impacts on water use and quality and there is the risk of trading off increasing agricultural output against decreasing water availability or quality with environmental or social impacts. These interactions lead to a need to balance across food, water, land, and energy, rather than simply thinking about maximising food production. The breadth of the intellectual challenge requires greater interdisciplinary thinking than has hitherto been the norm, and requires significant cooperation across the EU (and beyond) as no single country can invest sufficiently to fully address the challenge. We therefore need to encourage more strategic approaches to building interdisciplinary research programmes, and aligning national and international efforts.

Just as research typically exists in disciplinary silos, policy is often also disconnected. Economic policy may not align well with environmental, climate-change, energy or health policies. Industries are also inherently narrow, with a focus, for ex-

ample, on food, water, energy, or biofuels. As much as interdisciplinary research is needed, it is also important to encourage innovation to bring a better balance between the production of food (and its economic potential), its impact on and competition for water resources, and the sustainability of ecosystem services that are public goods. This will require greater sophistication in the regulatory and policy environment. However, policy, to be effective also needs to be simple and transparent. This presents a paradox. Research has an important role to play to embrace the complexity of the food system, but it should also help find routes through the complexity to develop simple, effective and joined-up policy.

An important part of sustainable economic development is via facilitating the "bioeconomy" — the emerging cross-cutting economic sector that produces, transforms, and uses bio-based materials. This is inherently trans-disciplinary, but, if not well promoted, it may generate new competition between biomass and food, and between production of bio-based material and other environmental services. However, there are important synergies between technologies and creation of new links in and between value chains (e.g., production of biochemicals alongside production of biofuels, use for waste, bio-based products in chemical and building materials industries). The essence of such transformational strategies are not only technological (new science) and behavioral (adjusted consumption), but also institutional, i.e., providing the regulatory framework and long-term incentives for industry and consumers, both at national and international levels. Sharing new bioeconomy knowledge from science systems of rich countries with developing countries and support for adaptation to local circumstances is an opportunity for collective action.

Investing in and aligning research

Each country exists in a globalised world and is affected by drivers beyond its borders, and therefore is a stakeholder in the global challenge; yet no single country has the resources to fully research (and understand) the issues around global food and nutrition security. EU research investments, such as Horizon 2020[68], are a crucial component of generating knowledge that is both of national and supra-national interest. Furthermore, significant value added can be gained by coordinating and aligning national and EU research strategies. Finding ways to identify common research priorities on a global scale is important to avoid competition with other countries globally, or wasted effort by not aligning similar investments or missing strategically important knowledge gaps on the assumption that "some other country is doing that". Within the EU, alignment is brought about via the Joint Programming Initiative[69] (such as FACCE: *Agriculture, Food Security and Climate Change* and HDHL: *Healthy Diets for a Healthy Life*) and ERA-NETs[70], aided by the Standing Committee on Agricultural Research (SCAR[71]). Internationally a range of other instruments (e.g. Future Earth, OECD, G20-sponsored projects) is available. Some member states have innovative partnerships for aligning research and interdisciplinary analysis across areas, such as the UK's cross-government Global Food Security Programme. These mechanisms need to be developed at national and supra-national scales (within the EU and between the EU and partners in other regions) fully to gain collective value from each research investment.

Transferring research knowledge into innovation and practice

Research creates the most societal benefit when the knowledge is used. Across the world, governments grapple with the "valley of death" between research undertaken and its uptake into innovation and use. Facilitating the green innovation economy requires building bridges across this valley. This may require greater linkage between stakeholders who are end-users and research providers. Such linkage needs to be encouraged throughout the research process (including in the co-design of research programme, and participation in steering research which can help provide "pull" for the use of the knowledge). Although in stimulating knowledge-into-use stakeholders are primarily identified as associated with industry, with the driver being economic growth arising from using research. Civil society also has a stake that may be non-financial, and may be associated with the development of social rather than technological innovation.

A recurrent challenge to the research and innovation system is stimulating two-way knowledge flow, allowing practitioners to access knowledge for implementing the "best practice" and allowing researchers to understand and address practitioners' needs. New research is not always needed as what we already know can be a platform for innovation if the knowledge is easily available and accessible. We therefore need to enhance knowledge structures and systems that allow data to be comprehensively shared, from which decision tools can be developed, and information accessed by end-users. This may include developing "honest knowledge brokers" or "trusted intermediaries" to ensure end-user trust in the information. It may also include enhanced efforts for user-involved research, such as developing networks of farmers involved in on-farm research and innovation and aiding them in the role of knowledge champions[72] for peer-to-peer learning.

The EU has already had significant impact in developing the innovation culture. For example, the European Technology Platform *Food for Life*[73] was launched in 2005, and is an industry-led public-private partnership aiming to foster research-into-innovation in the food sector.

Education and communication to the public

Food is a wonderfully integrative issue as it covers a broad range of academic and applied issues, and promoting understanding of the food system, and respect for food, within school and university education would lead to positive societal outcomes. The challenges in meeting food and nutrition security involve societal choices about pathways to achieve goals (for example, there is increasing discussion about changing diets for public health and environmental benefits), and many of these choices require social innovation and attitudinal change across society. This, in turn, needs greater public understanding of the issues around food production, environment, nutrition and health.

Where can the EU add most value?

The EU is a unique entity with coordination in research, policy and practice across a large number of countries, geo-climatic regimes and cultures. The EU hosts a huge human capital of researchers, with significant amounts of world-leading expertise. Many of the issues raised by the food and nutrition security challenge are inherently interdisciplinary, multi-sectoral and culturally-entrenched. The significant Horizon 2020 investments are aimed to undertake strategic-and-policy-relevant research for the benefit of the member states, and we already have a strong track record of coordination between research providers, within and across countries, between research users across policy domains; indeed this is an area where we are arguably world leading. The EU therefore has an important role to play in delivering research to overcome these challenges, but also showing international leadership in research and innovation into use for economic and societal benefits: enhancing health and well-being, sustainability and generating economic growth and employment.

There is scope for the further development of mechanisms for enhancing research-into-use, via:

- Developing research prioritisation to ensure that knowledge is generated across the complex global agri-food system that leads to the most positive impacts for the health of the public, environment and economy.
- Developing instruments for aligning complex research challenges across complex societal needs that change across space (within and between member states and beyond).
- Developing a sophisticated and inclusive innovation culture building on the European Innovation Partnerships, within Europe as well as beyond (e.g. in Africa).
- Facilitating a sustainable bioeconomy and sharing related science and institutional knowledge internationally.
- Developing channels of communication and knowledge exchange that are inclusive and respectful of cultural complexity.
- Developing models of governance for delivering sustainable agriculture and nutrition from local to supra-national scales.

ENDNOTES

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The present discussion document gives an overview of where European research can add the most value in relation to tackling food and nutrition security challenges and points to areas where we can expand our research potential. Moreover, it highlights the need to develop a governance structure that will allow sharing of best practices and facilitate the transfer of knowledge and innovation to feed the planet sustainably. It should stimulate a global discussion with stakeholders and the general public, ultimately shaping a legacy for Expo 2015.

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