European Commission

A **strategic approach** to EU agricultural **research & innovation**

Draft paper

Agriculture and Rural Development

CONTENTS

This document has been prepared for the European Conference: **"Designing the path: a strategic approach to EU agricultural research and innovation"** - 26-28 January 2016, Brussels

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CHAPTER 1

Why a strategy for agricultural research and innovation?

Evidence suggests that investment in agricultural research generates significant economic and wider societal returns notably through its impact on productivity[1] and food security. It also delivers environmental and social benefits even though these are harder to quantify.[2]

Despite its vital role, agricultural research has become a lower priority in high-income countries in recent decades compared with other areas.[3] Societies and policymakers were reminded of its importance in the late 2000s with the agricultural commodity price surge of 2007/08 and concerns over long-term food security arising from long-term agricultural projections made by the Food and Agriculture Oganization of the United Nations (the FAO) and other institutes and agencies and also concerns raised by long-term impact of climate change on agricultural production. As a result, there is now renewed interest in agricultural research and its potential to ensure environmental and basic societal needs in the context of the evolving challenges as described in this paper.

Research is expected to address immediate problems while at the same time anticipating future needs. Today's research will guide tomorrow's farming solutions and approaches. Incorporating research and innovation activities into a long-term strategy[4] will make it easier to identify strategic areas of short-, medium- and long-term interest, and so **improve their overall consistency, sequencing and impact**. A long-term view on research questions and investment is particularly important given the time lag between the initiation of research, the delivery of results and their uptake by users and ultimate translation into mainstream practice. In agriculture this process may take decades[5] and is further complicated by the fact that the solutions proposed need to be adapted to the site-specific context. In forestry this process is even longer due to long production cycles and regional features of both production and management systems.

Laying down strategic priorities for agricultural research in the EU will make it possible to better coordinate the activities of different funding bodies and develop synergies with Member States and non-EU research programmes. Joint efforts should provide a solid basis for sustained investment in agricultural research and build critical know-how and capacity over a longer period of time.

The strategy is meant to be an input in programming the remaining three years (2018 to 2020) of Horizon 2020 and in guiding agricultural and forestry research and innovation activities after 2020.

1.1. Major challenges faced by agriculture and food systems in Europe and globally

Agricultural and forestry activities provide the basis for food and non-food production under a wide range of conditions. In doing so, they also drive development in rural areas, impact on ecological services and deliver wider public goods. These multiple functions are performed in the context of major demographic, economic and environmental challenges which are changing the landscape of food and non-food systems[6] in which land-based primary production is taking place.

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[1] See for example Alston J., *The benefits from agricultural research and development, innovation and productivity growth*, OECD, 2010.

[2] *Measuring the Environmental Impacts of Agricultural Research: theory and Applications to CGIAR Research*, CGIAR, 2011.

[3] In high-income countries, the average annual growth rate of public investments in agricultural research fell from 2.0% in the period 1981-1990 to 0.8% in the period 2000-2008 (see *ASTI global assessment of agricultural research and development spending*, IFPRI, 2012). In addition, low agricultural prices prior to 2007/2008 did not favour investments (including in research) in the sector.

[4] See *Sustainable food consumption and production in a resource-constrained world*, Standing Committee on Agricultural Research (SCAR), European Commission, 2011.

[5] *Analyse des impacts de la recherche agronomique publique*, INRA, 2014. An estimate of an average time span at 30 years is provided in Alston J. et al., The Economics of Agricultural R&D, *Annual Review of Resource Economics,* 1, 2009, pp. 537-565.

[6] In this paper food system refers to the processes that describe how food from a farm ends up on the table of consumers. These processes include production, processing, distribution, consumption and disposal. Food supply chains are the main building blocks of a food system.

Food security[7]

World **population growth** will continue to put pressure on food production. Not only will there be more people to feed, but as the average income in many developing countries is expected to rise, there is also likely to be greater demand for higher quality and processed food. In addition the worldwide trend towards greater urbanisation is expected to continue over the next few decades, and this will also affect dietary patterns.[8]

The FAO has projected that agricultural production needs to rise by 60% by 2050 compared with 2007 levels to meet the projected demand for food and other uses. This figure is considerably lower than the increase achieved in the previous four decades (1.1% annual average growth throughout the period 2007-2050 against 2.2% in the last decades).[9] However, past growth took place when there were fewer constraints on resources and the effects of climate change were more limited. Specifically, production growth will have to be achieved despite more stringent constraints on water availability and without the potential for large areas of additional agricultural land.

The 60% projected increase would consist in a 77% increase in developing countries and a 24% increase in developed countries. In the former, many of which have the highest projected population growth by 2050 (especially those in Africa), current production levels are far below their potential. Raising **agricultural productivity in a sustainable manner** is thus necessary. Irrespective of changing global circumstances, the long-term projections for supply and demand in most developed countries, including in the European Union, suggest that it is possible to achieve the growth rates in supply that would ensure food security. Therefore, the critical issue in Europe is rather to boost all aspects of production sustainability, without underestimating the importance of maintaining a sufficient and dynamic production base in a more uncertain world.[10]

Although total food production at global level could theoretically feed the world's population, 800 million people are suffering from chronic under-nutrition,[11] three quarters of whom are living in rural areas in developing countries and depend to a large extend on farming activity. Access to food should not, therefore, be overlooked. At the same time there is an upward trend in **malnutrition** in both developing and developed countries, imposing a large cost burden on societies. Appropriate supply of **nutritious** food is key to mitigate health problems related to malnutrition. It will be necessary to sustainably increasing production at global level, yet this is only one aspect of the issue of food security. **Food losses and waste** are estimated at around 30% of total food produced,[12] therefore reducing waste is crucial. Finally, the **safety** of food supply is mandatory for health, social and economic reasons.

[7] We use the FAO definition of food security throughout this paper: "***food security*** *exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life*" (World Food Summit, 1996). Food security has four main dimensions: food availability, food access, utilisation and stability. Food security is sometimes referred as food and nutrition security.

[8] See for example 'Global Food Security 2030', *Foresight Series*, Joint Research Centre, European Commission, 2015.

[9] See: Alexandratos, N. and Bruisma, J., *World Agriculture towards 2030/2050, the 2012 Revision*, FAO, 2012. According to the FAO, global annual production grew at 2.2% on average in the period 1961-2007. It is expected that the average annual rate of growth of agricultural production will decrease in response to a deceleration of demand growth, partly as a result of the slowdown in population growth. Nearly 90% of the increase in production is expecting to come from developing countries, this would raise their share in world agricultural production from 67% in 2005/2007 to 74% in 2050.

[10] It should not be forgotten that agricultural productivity varies quite significantly between and within Member States and has substantial potential growth in several of them. Furthermore, the plateauing of crop yields observed in Europe in recent decades (partly due to climate change) highlights the importance of maintaining or even increasing yields, and justifies substantial investments in breeding.

[11] *The State of Food Insecurity in the world 2014*, FAO, 2015.

[12] *Food wastage footprint, impact on natural resources, summary report*, FAO, 2013.

CHAPTER 1

Environment and climate change

Natural resources - such as soils, water and biodiversity - face strong pressures partly owing to inappropriate agricultural practices and overuse.[13] The State of the Environment Report of the European Environmental Agency shows that agricultural activities have a significant impact on the management of natural resources. [14] The report indicates how environmentally-harmful farming practices cause soil degradation and water contamination, reduction in pollinators, loss of natural biological control of pests and diseases and of plant and animal genetic diversity.

In addition, **climate change** is a major global challenge. Agriculture accounts for about 10% of EU greenhouse gas emissions including more than half of the non-CO_2 gases.[15] Globally, agriculture and forestry are the source of 24% of emissions, including through tropical deforestation driven primarily by conversion to agriculture.[16] The agricultural sector, together with forestry, will have to contribute to the reduction of greenhouse gas emissions and climate change mitigation while simultaneously adapting to climate change. Agriculture, forestry, environmental protection of natural resources and climate change need to be considered in an integrated manner.

Agriculture and forestry are increasingly affected by threats and shocks attributed to climate change (e.g. the increase in extreme weather events), plant and animal diseases and economic factors (e.g. price volatility). Climate change and water scarcity contribute also to loss of agricultural land which exacerbates pressures on remaining agricultural land. Strengthening the **resilience of farming and forestry systems,** and beyond of food and non-food systems, is therefore essential.[17]

Finally, growing population, rising income and global shifts towards consumption patterns richer in animal proteins will further increase pressures on agricultural resources and forests. Therefore, dealing with the sustainability of consumption patterns will be necessary.

Growth and jobs in rural territories

The EU agri-food sector, including food retail and services, currently employs 44 million people – many in rural and remote areas – and it depends on a farm sector capable of ensuring a steady supply of raw materials. The EU's 12 million farms provide full-time equivalent jobs to 9.7 million persons and generate €160 billion of value added.[18] The farm sector has to meet consumer demands within a system where the upstream and downstream sectors are increasingly concentrated and where **competition on global markets** is increasing. The farm sector is characterised by fragmented structures and producer income levels which remain, on average, significantly below income levels in the rest of the economy. It is facing significant structural adjustment (e.g. the decreasing number of farms, ageing of farmers, the development of salaried work, and the diversification of activities). **Economic viability** of farming and attractiveness to the younger generation are a prerequisite for food security. On-farm working conditions are evolving constantly and **social conditions** in the farming sector deserve appropriate attention.

The forest-based sector represents 8% of manufacturing added value in the EU, provides income for almost 16 million forest owners and has a workforce of over three million people.[19]

Primary production interfaces with upstream and downstream sectors which both contribute significantly to jobs and growth creation.[20] Agriculture and the forest-based sector are also major producers of biomass for uses other than food or feed, such as biofuels, biochemicals and biomaterials. They are important contributors to the **bioeconomy**.[21] New value chains offer additional opportunities for agricultural and forestry production and activities in the rural economy to shift from the fossil-based to the bio-based economy. Avoiding additional pressure on resources will be necessary to seize these opportunities sustainably.

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[13] See *Global Environmental Outlook, GEO-5*, UNEP, 2012. In the case of the EU, several European Environment Agency publications have shown the extent of biodiversity losses in EU agro-ecosystems (for instance farmland birds). It is estimated that 75% of the utilised agricultural area is affected by erosion by water, of which almost 20% is subject to soil loss in excess of 10 tons / hectare / year. Water resources, of which agriculture uses more than one-third, are also under increasing pressure in the EU. For instance projects show that the number of river basins under water scarcity is expected to increase by up to 50% by 2030 (COM(2012) 672 final). Agriculture is also the source of 90-95% of ammonia emissions. Their reduction is one of the objectives of the Clean Air Policy Package adopted by the Commission in December 2013 (COM(2013) 918 final).

[14] *SOER 2015 – The European environment: state and outlook,* European Environment Agency, 2015. Http://www.eea.europa.eu/soer.

[15] Global figures: *Climate change (2014) synthesis report*, IPCC, 2014. For the EU: see Eurostat, Agriculture - greenhouse gas emission statistics.

[16] Fifth Assessment Report of the Intergovernmental Panel on Climate Change, agriculture and forestry contribute to GHG mainly and agricultural emissions from livestock, soil and nutrient management (CH4 and N2O emissions) and through deforestation. See: http://www.ipcc.ch/report/ar5/wg3/.

[17] See *Sustainable agriculture, forestry and fisheries in the bioeconomy – A challenge for Europe*, Standing Committee on Agricultural Research, European Commission, 2015.

[18] Sources: Eurostat data, elaboration DG AGRI. Number of farms and employment concerns 2010, value added is average 2012-2014. Employment in agriculture, forestry, fisheries and hunting (primary sector) represents 5.1% of EU total employment in 2010. See EU agriculture - Statistical and economic information – 2013 available at: http://ec.europa.eu/agriculture/statistics/agricultural/2013/index_en.htm.

[19] *Strategic research and innovation agenda*, Forest-based Technology Platform, 2013.

[20] The food sector generates €225 billion value added in 2010-2012 and is a net exporter of high-value added products. Source: Eurostat, elaboration DG AGRI (reports Rural Development in the European Union - Statistical and economic information available at: http://ec.europa.eu/agriculture/statistics/rural-development/2013/index_en.htm).

[21] COM(2012) 60 final.

Research and innovation can contribute significantly to the competitiveness of EU food and non-food systems on export markets.

It is important not to forget the **territorial dimension** of agricultural, forestry and related upstream and downstream activities. Rural areas, which still account as a whole[22] for 55% of EU jobs and 46% of gross value-added, are going through a period of profound economic, demographic and institutional transformation. Globalisation, decentralisation, urbanisation, migration trends and the emergence of new product and service markets present new challenges and opportunities. Rural areas may have a number of assets (e.g. natural resources or cultural resources) that could contribute to boosting growth and reducing the economic divide with other regions. However, despite sustained growth in rural areas, there is still a gap between rural areas on the one hand and urban and intermediate areas on the other: in 2010, the GDP per capita in predominantly rural regions stood at 70% of the EU average.[23] Recent research has however highlighted positive trends in rural growth[24] and significant variations between rural areas, with some areas growing faster than some urban areas, while others are in decline. Encouraging **cohesion and convergence** between the various parts of the EU is one of its core objectives. Sustainable growth and a balanced territorial development are needed to achieve the objective of "**jobs, growth and investments**" of the European Commission.

1.2. Contribution of agricultural research and innovation to the objectives of EU policies

The general objective of Horizon 2020 is to contribute to building a society and an economy based on knowledge and innovation across the EU. The programme aims to strengthen EU scientific and technological bases by, in particular, encouraging the EU to advance towards a knowledge-based society and to become a more competitive and sustainable economy. Horizon 2020 has been assigned a central role in supporting the Europe 2020 strategy for smart, sustainable and inclusive growth, highlighting the role of research and innovation as key drivers of social and economic prosperity and of environmental sustainability.

Research plays a crucial role in contributing to the design and implementation of EU policy by providing a sound evidence base. As part of the Horizon 2020's Societal Challenge 2 ('Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy'), agricultural research and innovation is integrated into and provides support for a range of EU policies, including the Common Agricultural Policy (CAP), the EU Forest Strategy[25], international development, health, environmental policies, climate action and waste reduction policy.[26]

Evidently, the way in which research supports policies must take account of how policy changes over time. For example, the following initiatives will have a significant bearing on agricultural and forestry research: the Energy Union Package adopted in 2015, the outcome of the 2015 Paris climate conference, the EU's 2030 climate framework, the Circular Economy Package[27], the review of the EU's Bioeconomy Strategy, the mid-term review of the Biodiversity Strategy and, of course, the CAP.

This strategy will contribute to the implementation of the **Sustainable Development Goals** (SDGs) adopted in September 2015, for both domestic and external policies of the EU. Most of the targets under Goal 2 'End hunger, achieve food security and improved nutrition and promote sustainable agriculture' are relevant for agricultural research.[28] The strategy will also contribute to the achievement of the following SDGs:

- Goal 12 'Ensure sustainable consumption and production patterns'
- Goal 13 'Take urgent action to combat climate change and its impacts'

[22] If we consider together predominantly rural areas and intermediate areas.

[23] Eurostat data, elaboration DG AGRI. Available at: http://ec.europa.eu/agriculture/statistics/rural-development/2013/full-text_en.pdf.

[24] *Rural-urban partnerships, OECD Rural policy reviews*, OECD, 2013.

[25] COM(2013) 0659 final.

[26] See description of Societal Challenge 2 in Annex I of Regulation (EU) No 1291/2013 of the European Parliament and of the Council of 11 December 2013 establishing Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020).

[27] *Closing the loop - An EU action plan for the Circular Economy* (COM(2015) 614/2).

[28] 'End hunger and all forms of malnutrition; double agricultural productivity and incomes of small-scale food producers; ensure sustainable food production systems and implement resilient agricultural practices; maintain genetic diversity; increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries.'

- Goal 15 'Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss'

In the recent years, the synergies between Horizon 2020 and the CAP have been strengthened. Agricultural research and innovation under Horizon 2020 aims to support the main objectives of the CAP in the areas of viable food production, sustainable management of resources and climate action and a balanced territorial development.[29] To achieve these goals it is important to bridge the gap between theory and practice to enable the agriculture sector and rural areas to become more sustainable and competitive and capable of adapting to new challenges. Innovation – together with climate change and environment – is a cross-cutting objective under the Rural Development pillar of the CAP. The European Innovation Partnership 'Agricultural Productivity and Sustainability' (EIP-AGRI) relies on both policies to encourage innovation and support knowledge-based agriculture. In particular it provides support to rural actors to exchange knowledge and join forces to solve particular problems.

In a nutshell, EU agricultural research and innovation will support transition pathways towards resilient, sustainable and climate-friendly farming systems. It will ensure productivity while taking all sustainability dimensions (environmental, economic and social) into account.

It will contribute to research efforts aimed at improving the sustainability of food and non-food systems and to progress on global food security.

[29] COM(2010) 672 final.

CHAPTER 2

What priority areas for research and innovation?

2.1. Scope of the research and innovation strategy and interface with other research areas

The strategy focuses on land-based primary production, centred around agriculture and forestry, but also extends to food and non-food chains and the rural economy. It considers relevant interfaces with other sub-sections of Societal Challenge 2 (e.g. marine research) and with other parts of Horizon 2020.[30]

Close links will be established with the part of Societal Challenge 2 dealing with food. This will concern in particular such aspects as **food safety** and **food quality** with the aim to producing better quality, healthier food that meets consumer needs. In addition, the strategy will contribute to the European Food Research Area, to be launched in October 2016, which will ensure coherence of all research and innovation efforts in the field of food security.

2.2. Cross-cutting issues

2.2.1. Systems approach, interdisciplinarity and transdisciplinarity

The need for a **systems-based approach** towards research has been emphasised in several reports and bodies[31] (e.g. the third and fourth Standing Committee on Agricultural Research (SCAR) Foresight reports, the International assessment of agricultural knowledge, science and technology for development (IAASTD) and the Expo 2015 EU Scientific Steering Committee). Meeting the challenges facing the agricultural and food and non-food systems means working in an integrated manner so that the proposed solutions are fit for both the problem they address and the main objectives being pursued for the system as a whole, such as the food system. In addition such an approach should provide information on the impact of the various actors on the other parts of the system (e.g. the role of consumer preferences in the food chain). This requires the encouragement of interdisciplinary (e.g. the Expo 2015 EU scientific steering committee) or even transdisciplinary (the fourth SCAR Foresight report) approaches. In addition, most papers stress that it is essential to encourage the implementation of research results and innovation on the ground.

A systems-based approach will be implemented in relevant areas in order to ensure that activities carried out take account of both the immediate objectives they target and the wider objectives of the research programme. The system-based approach implies to add, to the research done at the level of the components of the system, research meant to understand the interactions between the components. Such approach will be implemented at both project (or cluster of projects) and programme level. At project level, the wider context in which projects are being carried out (e.g. the food chain) will be taken into consideration. This is already put into practice, as the activities under a series of projects from the Horizon 2020 work programme 2014/2015 and topics from work programme 2016/2017 extend beyond the primary sector to the food and non-food supply chain. In addition, **interdisciplinary**[32] and **transdisciplinary**[33] approaches will be encouraged **wherever relevant**.

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[30] For instance ICT (under pillar II of Horizon 2020) or Societal Challenges such as 'Health, demographic change and well-being' (Societal Challenge 1) or 'Climate action, environment, resource efficiency and raw materials' (Societal Challenge 5).

[31] *Agriculture at a crossroads, International assessment of agricultural knowledge, science and technology for development*, IAASTD, 2009; *Sustainable food consumption and production in a resource-constrained world*, SCAR, European Commission, 2011; *Sustainable agriculture, forestry and fisheries in the bioeconomy – A challenge for Europe*, SCAR, European Commission, 2015; Global Food Security *2030, Foresight Series*, Joint Research Centre, European Commission, 2015; *The role of research in global food and nutrition security* and *The European research and innovation agenda for global food and nutrition security*, Expo 2015 EU Scientific Steering Committee, 2015.

[32] Interdisciplinary research involves closer and more frequent collaborative exchanges among researchers drawn from different fields who are working together on a common problem.

[33] Transdisciplinarity is a specific form of interdisciplinarity in which boundaries between and beyond disciplines are transcended and knowledge and perspectives from different scientific disciplines as well as knowledge from societal stakeholders are integrated.

At programme level, the strategic management of the portfolio of activities will ensure the proper alignment of the various activities with the overarching objectives. Finally, implementing **nexus approaches**, i.e. involving research and innovation in several sectors, such as food, water, energy and biodiversity will be sought. Such approaches allow to reduce trade-offs and develop synergies between sectors.

2.2.2. ICT as an enabling technology for research and innovation

Smart and mobile technologies are hailed as one of the most important recent innovations for all actors in food and non-food supply chains all over the world allowing access to a host of services from real-time market information to crop disease identification. Beyond assisting in primary production (e.g. precision farming), ICT has immense potential to support many elements of the rural economy, from food and non-food supply chain management to new business development.[34] Research is necessary at three main levels: (1) the 'infrastructure' level (interoperability of data and information systems) to facilitate the use of ICT; (2) the 'systems' level (smart sensors and actuators deployed within robotic and automated systems); and (3) the 'application' level in various parts of the rural economy. Private and public goods and services will be sought from opportunities created by the internet of things and big data approaches although unresolved issues such as data ownership and user rights will have to be taken into account. ICT will also be an enabler in the research process (e.g. the generation, use and sharing of research data and crowd science).

2.2.3. Enabling sciences and infrastructures

Public funding is important for basic research and infrastructures. These are areas where private funding is more difficult as it tends to be channelled into applied research.

Enabling sciences have a key role to play for fundamental understanding of biological processes, from molecular biology to cells, organisms, populations and ecosystems. They include genomics, statistical modelling, benchmarking, pilot systems facilitating the collection of data and information to support evidence-based, science-informed policies, decision-making and technology development. In addition, more sophisticated and reliable **benchmarks** are required to set targets and monitor and compare agricultural and forest resource efficiency and the environmental footprints of management options and farming systems at various levels, including the global level.

A reflection needs to take place together with Member States on infrastructures needed to facilitate research and innovation at EU level. This reflection would include e-infrastructures (to facilitate data use and sharing and to curate research outputs) and infrastructures that link experimental and demonstration farms, etc.

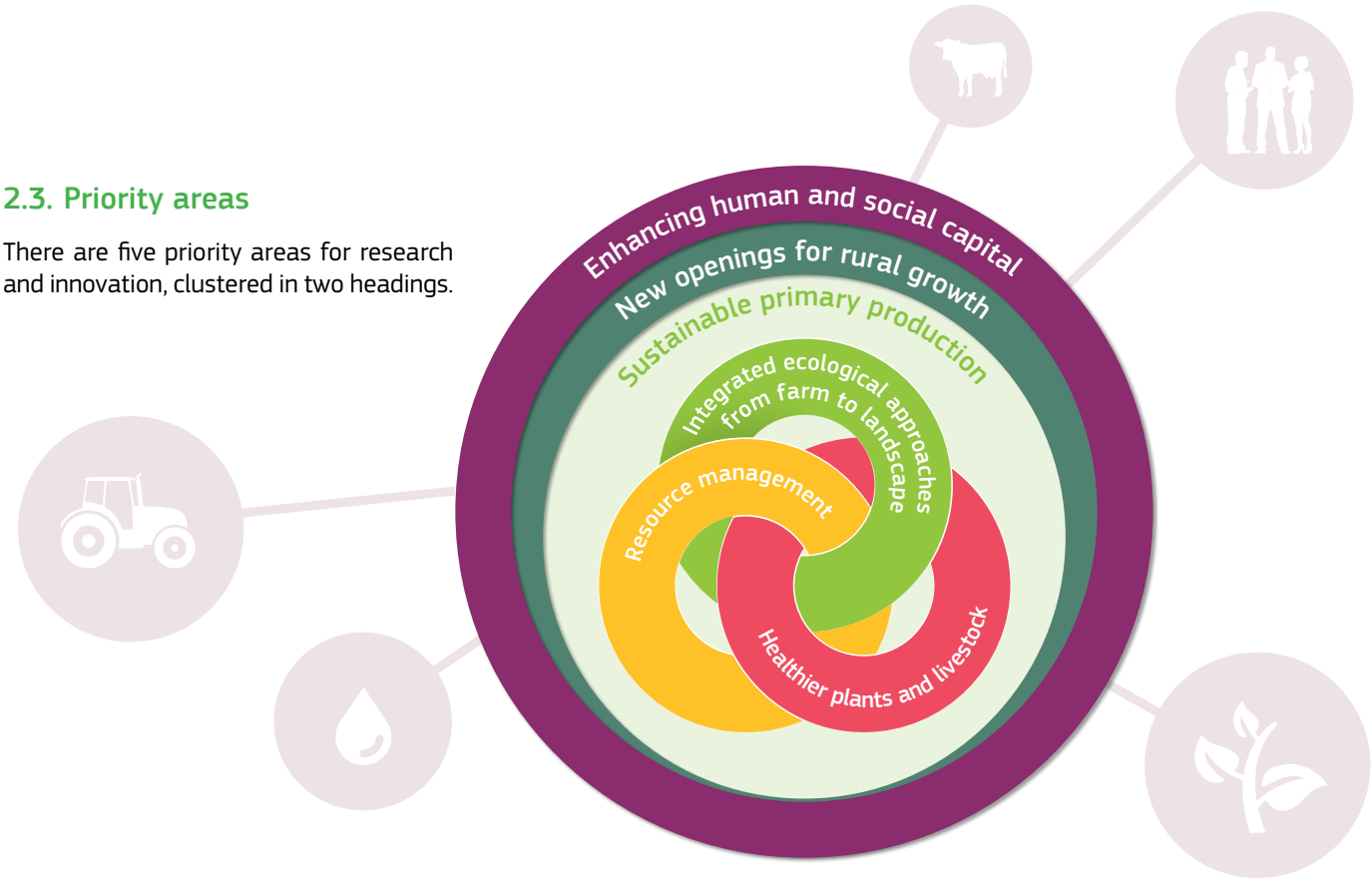
[34] Several recent foresights assign a major importance to the role that ICT can play, see in particular the fourth SCAR foresight which speaks of an ICT revolution.

2.2.4. Socioeconomic research and support for EU policies

The system-based approach requires socioeconomic research to be embedded in all relevant research and innovation activities. Research, in particular socioeconomic research, is critical to the design and implementation of efficient and effective **policies** affecting rural territories and food and non-food systems. This concerns a range of policies, not just the CAP, and requires attention at various levels (from the individual to the society and from local to global). In particular, research has a strong role to play in contributing to the development of the analytical tools and models which are necessary for assessing the EU policies concerned. In view of the various objectives that apply to policies targeting agriculture, forestry and the rural economy at large (e.g. economic, environmental objectives), it is important that these analytical tools and models are able to cover a larger range of issues at various geographical scales. Socioeconomic research needs to be harnessed to assess the economic sustainability of the various activities relevant in rural areas, including farming activities, taking due account of the social and environmental dimensions. The development of suitable standards to measure, assess, monitor and ensure a healthy functioning of the food or non-food supply chains will be given due attention. Finally, socioeconomic research will play a key role in establishing appropriate interfaces between research and society. Societal engagement in research and innovation is especially important.

2.3. Priority areas

There are five priority areas for research and innovation, clustered in two headings.



Heading 1: Creating value from land - sustainable primary production:

- Resource management (notably soil, water, biodiversity)
- Healthier plants[35] and animals
- Integrated ecological approaches from farm to landscape level

Heading 2: Enhancing rural innovation - modernising rural territories and policies:

- New openings for rural growth
- Enhancing the human and social capital in rural areas

The five priority areas are not meant to be separate blocks but in fact reflect the interconnections between challenges and solutions. For example, some of the research orientations proposed under 'healthier plants and animals for sustainable production and human health' will contribute to 'resource management'. Thus there are obviously some overlaps between these five priorities, and research on specific issues may be carried out under several priorities but from different angles. Research topics will take this into consideration and, if necessary, will cut across several priorities so as to integrate all important aspects.

In the first heading, the third priority on 'integrated ecological approaches' capitalises on the ones on 'resource management' and on 'healthier plants and animals'. This priority area aims to look at the interactions in a systemic approach between those areas and between the different challenges. While the first three priorities focus mainly on primary production systems, the priority on 'new openings for rural growth' looks at integrated food and non-food supply chains and systems from a territorial perspective.

In many cases, research has already been carried out in the above-mentioned areas. The objective is not to duplicate existing knowledge but to take it further and to facilitate its implementation.

[35] Throughout this paper, the term "plant" includes trees and shrubs.

2.3.1. Creating value from land: sustainable primary production

Agriculture has evolved over thousands of years into a range of often highly specialised and high yield production systems. These reflect the diversity of climatic and geographic conditions, cultural specificities and ever-changing consumer demands. However, advances in productivity have not been distributed evenly and often have come at significant environmental cost, thereby leading to mounting concerns over the sustainability of current ways of production.[36] The environmental and social dimensions of agricultural production are coming under further scrutiny as a result of increasing evidence of the links between food and human health.

This part of the strategy focuses on resource management, plant and animal health and underpinning ecological approaches as these three areas lend themselves well to illustrating the agriculture-food-environment interface. They are described below to show how research can support pathways for the creation of economic, environmental and social value from land.

2.3.1.1. Resource management

Activities in the primary sector depend heavily on the **availability and quality of natural resources** such as land, nutrients, water and biodiversity. At the same time the primary sector impacts directly and indirectly on the integrity of these resources and contributes significantly to their depletion. Resources such as water, land and specific nutrients are already being overused.[37] Pressures on natural resources are further exacerbated by increased environmental variations resulting from climate change, to which agriculture is also contributing.

Research on agricultural resource use will aim to safeguard the long-term productivity of the sector as well as reduce its adverse impacts on ecosystems and human health. These goals will be pursued by encouraging efficient resource management as well as resource restoration and conservation, in particular taking into account the interactions between ecosystems, climate, agriculture and resources. Efforts will be undertaken to: better understand the medium- to long-term impacts of climatic variations on land-based primary production; support strategies for the adaptation and resilience of the farming and forestry sectors; and strengthen agriculture's contribution to mitigation of greenhouse gas emissions. The livestock sector is facing particular challenges. While it is a source of high quality nutrients, firmly embedded in human diet and potentially providing important ecosystems services, current methods of livestock production require significant amounts of land, energy and water resources and contribute significantly to greenhouse gas emissions. New approaches are needed to reduce these trade-offs and improve resource efficiency of livestock production.

A research agenda for tackling resource use is complex as it needs to consider the various levels at which the use of resources can be optimised – ranging from more efficient use of resources at the level of plants and animals, to agro-ecosystems and value chains. At a

[36] See Short version of 2012 UN report: Sustainable Development in 21st century. Food and Agriculture: The future of sustainability https://sustainabledevelopment.un.org/content/documents/1443sd21brief.pdf.

[37] World Resources Forum: http://www.wrforum.org/publications/opinion/planet-earth-limits-natural-resources.

broader level, in relation to land use, cooperation between farms as well as rural-urban interactions will provide opportunities for linking urban and agricultural resource flows (e.g. water and waste - see also section 2.3.2 on rural innovation). These synergies are likely to expand as the concept of a **circular economy** gains momentum. In the area of agriculture the implementation of the circular economy is expected to lead to new ways of valorising and using residues and by-products, operating farms and reducing the use of natural resource inputs.

With regard to technology, expectations are high that the increased availability of data and their interconnectivity through the use of **ICT, predictive tools, robotics and precision technologies** will significantly increase resource efficiency of farm operations (in terms of time and land), and improve their environmental performance. The combined use of prediction models and monitoring sensors for example, can support precision irrigation, nutrient or weed management. Combined with management approaches such as crop rotation, intercropping or agro-forestry the use of these tools can lead to significant improvements in nutrient and water use efficiency of crops.[38] In addition, changes in the use of fertilisers have an immediate bearing on the emission of climate relevant nitrous oxide emissions and in more indirect ways also on human health (through improved air quality). In livestock, precision technologies have the potential to improve efficiency in the management of animals as well as to reduce greenhouse gas emissions, for example through precision feeding, or monitoring animal health and welfare.

As agricultural activities are increasingly moving outside rural areas, attention will be given to **urban farming** and its potential to deliver multiple social, environmental and economic benefits. Urban farms are well placed to implement circular closed-loops production patterns, to re-use abandoned land and develop new producer-consumer relationships. Knowledge, technologies and social innovations are further required to fully exploit this potential.

[38] Draft report of EIP Focus group on Water & Agriculture: Adaptive strategies at farm level.

Land/soil, water and genetic resources are seen as a main focus for research under this priority as they are the basis of agricultural production and are particularly susceptible to overuse and mismanagement.

Research is crucial to better understand, monitor and measure the specific effects of agricultural activities and farming systems on **soils and its various productive and ecosystems functions**. Activities will pay attention to preserving and/or improving soil fertility and functions by optimising its biological, chemical and physical properties. This will include encouraging measures that increase soil carbon content as well as soil biodiversity and reduce soil erosion. Crops interacting effectively with the soil food web will better exploit the productive potential of soils. In addition to appropriate management practices such as crop rotation, fertiliser application and tillage, adapted machinery and tools for monitoring the status of soils are required to support changes in land cultivation and management. The knowledge and tools developed will serve to test and further develop soil enhancing farming systems taking due account of the role of livestock in the management of soil resources. Research efforts will seek to enhance the function of soils as carbon and nitrogen sinks, thereby supporting the role of agriculture and forestry in mitigation of greenhouse gas emissions as well as in combating desertification and land degradation.

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Knowledge and innovation are also required in the area of **agricultural water use and management** with the aim of reducing the heavy reliance on this increasingly scarce resource[39] and to reduce water pollution from agriculture. Research will tackle on-farm water management in different ways, for example by: exploiting the genetic variation of plants and animals; increasing knowledge on interactions between genotype, environment and management; supporting breeding for more adapted and resistant plant and animal varieties; and developing water smart farming systems. Research will promote novel precision technologies, computational tools and models which are able to connect different types of data (e.g. from plants and animals, soil and meteorology) in view of providing decision making tools or 'early warning systems' for smart water applications. Special attention will be paid to maximising the synergies between water, soil and land management, thereby taking into account the surrounding natural environment of farms. Water stewardship goes beyond the farm level. Its regional dimension, including policies, economic instruments and participatory tools, will be dealt with under the 'enhancing rural innovation' priority.

Genetic resources underpin agricultural production and are considered as a prerequisite for ensuring food security in a range of (changing) environments. Current food and non-food systems rely heavily on a small number of crops and breeds[40] and the preservation of genetic resources is seen as a way of sustaining breeding activities and coping with future demands in farming, forestry and consumption. Research activities will promote the *in-situ* and *ex-situ* conservation of a wide range of plant and animal genetic resources (including underutilised plant and animal breeds) and improve the links between these two. Activities will also improve the characterisation, information and access to genetic resources and support their use by breeders, farmers/foresters and in value chains for food and non-food products.

[39] On average, 44% of total water abstraction in Europe is used for agriculture (with levels going up to about 65% in Southern Europe); http://ec.europa.eu/agriculture/envir/water/index_en.htm.

[40] Of more than 50 000 edible plant species in the world, only a few hundred contribute significantly to food supplies. Just 15 crop plants provide 90 percent of the world's food energy intake, with three rice, maize and wheat - making up two-thirds of this: http://www.fao.org/docrep/u8480e/u8480e07.htm.

2.3.1.2. Healthier plants and animals

Transmissible animal and plant diseases and the measures necessary to control them can have devastating impact on agricultural sustainability as they entail production losses, reduced efficiency, generate trade disruptions and affect the whole economy. This has been experienced with epidemic diseases (e.g. foot-and-mouth disease, avian influenza, pine wood nematode), but also emerging diseases or endemic diseases (Campylobacter). These pests and pathogens can have a serious impact on human health and food safety either directly (e.g. zoonoses, i.e. diseases that can be transmitted between animals and humans), indirectly (e.g. chemical residues) or both (e.g. antimicrobial[41] resistance). In the animal sector, diseases are detrimental to animal welfare and their control is key to improving overall production efficiency and thereby decreasing the carbon footprint of production systems.

Plant and animal production are under mounting pressure due to the increasing number and frequency of new and re-emerging pests and pathogens resulting from globalisation, trade development and climate change which increase their potential to establish themselves and spread.

European agriculture needs to be granted sufficient means to cope with the above-mentioned threats to ensure food security and feed and other non-food products supply, avoid trade disruptions and ensure consumer confidence in food by mitigating potential risks to plant, animal and human health (including food-borne zoonoses). This extends beyond fighting pests and diseases to developing practices that would prevent their occurrence in the first place.

Plant and animal pests and diseases can have multifactorial origins resulting from inappropriate production conditions. For this reason, **animal and plant health must be examined using a systems-based approach** which includes the various elements of production (breeding, management, animal nutrition) and the environment including the use of functional biodiversity for pest and disease control. Increasing resilience and robustness is a key objective for animal and plant production and requires attention not only to transmissible diseases but also to other pathologies and animal welfare.

In addition such approaches as '**One Health'** will be considered. There is no single definition of One Health.[42] According to the FAO, it is a 'collaborative, international, cross-sectoral, multidisciplinary mechanism to address threats and reduce risks of detrimental infectious diseases at the animal-human-ecosystem interface'[43] and focuses not only on transmission disruption but also on the drivers of disease emergence. A broader definition refers to attaining optimal health for people, animals and the environment. This would go beyond infectious animal diseases and could include, for example, chemical substances and plant health.

[41] For the purpose of this document, antimicrobial resistance includes resistance to treatments against helminths (worms)

[42] http://veterinaryrecord.bmj.com/content/174/4/85.full

[43] http://www.fao.org/ag/againfo/home/en/news_archive/2010_one-health.html

The **societal dimension** of animal and plant health needs to be tackled, whether it concerns food safety and quality, animal welfare or perception of disease control measures and new technologies. Societal engagement on proposed approaches and measures needs to be sought from the outset.

Disease prevention is better than cure: research into measures that can reduce the risk of introduction and spread of pests and diseases in a farm/establishment or in a region, will contribute greatly to the objectives of sustainable production and human health. As regards livestock production, biosecurity measures including technologies, best practices and farmer behaviour are essential. The development of vaccines is a key component of the preventive fight against diseases in animals and, to a lesser extent, crops. Other products/approaches, including environmental ones, contributing to disease prevention or the control of affected animals/plants will need to be considered. As regards livestock, health and welfare indicators should be developed. The policy implications of prevention approaches will be investigated.

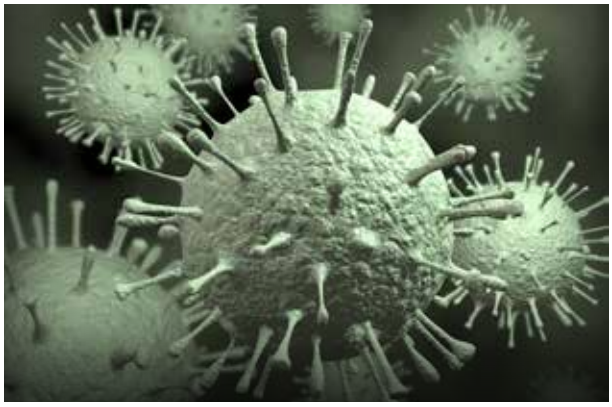
Tools to control pests and diseases need to be strengthened beyond the above (vaccines, alternatives treatments, biosecurity). This includes operational early detection systems (in particular for pathogens with pandemic potential); the assessment of sources; assessing the burden and impact of pests and diseases in order to develop cost-effective surveillance and control approaches/measures; developing forecasting tools that make use of ICT developments, making use of big data combined with autonomous farming systems; and innovative approaches to treat diseased animals/plants.

Addressing the issues related to the uses of pesticides in the plant sector and **antimicrobials** in the animal sector is essential to protect human health (e.g. to tackle problems associated with pesticide residues and antimicrobial resistance), animal health (e.g. to address antibiotic resistance), and for environmental reasons (e.g. avoiding water pollution, protecting biodiversity and wild pollinators). It is also important for safeguarding the long-term sustainability of the sector. In the plant sector, the implementation of Regulation (EC) 1107/2009[44] will lead to a reduction of the active substances available, which means that alternatives must be found. The slowdown in the development of new antimicrobials for human health is constraining the availability and use of antimicrobials for animals, in particular critical molecules. Research is necessary to provide producers with alternative approaches (enabling them to reduce the use of pesticides and antimicrobials) and/or facilitate their uptake, and to support the implementation of the Sustainable Use of Pesticides Directive, including integrated pest management[45] and the Action Plan against rising threats from Antimicrobial Resistance[46]. This research is even more vital in niche sectors that have been rather neglected by public and private research, e.g. the so-called minor crops and minor animal species sectors (e.g. goats, rabbits, or bees).

Dealing with **emerging risks** is a priority and ensuring preparedness is a challenge. In a number of cases, emerging diseases in animals often have their source in wild animals; they are zoonotic and outbreak may be first diagnosed in humans. Vector-borne diseases (transmitted by living organisms, e.g. mosquitoes, ticks, flies) are a growing problem in animals, partly because climate change is increasing the geographical distribution and prevalence of vectors.

In the livestock sector, the relationship between **animal feed and feeding** and health needs to be further investigated. In addition, the possibilities for improving **animal welfare,** through e.g. more appropriate management (including human-animal relationship in farming), need to be further explored.

Strengthening **basic research** is necessary on: the biology and ecology of pests and pathogens; animal/plant genetic make-up and biology (especially the microbiome and immunology); host-pathogen interactions (including plant-soil-microbe interactions); the connection between genotype and phenotype; system biology; biomarkers; and epidemiological modelling.



[44] Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market (OJ L309 24/11/2009 p.1).

[45] Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides (OJ L 309 24/11/2009 p.71).

[46] COM(2011) 748.

2.3.1.3. Integrated ecological approaches from farm to landscape[47] level

Agriculture and forestry have to meet the changing needs of society not only in terms of consumption (food security, food safety, non-food products, etc.), but also address the environmental issues relating to primary production (e.g. biodiversity, habitats, water quality and quantity, climate change, air quality).

A deeper understanding of ecological principles is changing views on the functioning of primary production systems and will make it possible to use ecosystem services[48] to benefit sustainable production. While advances in agriculture have often resulted from innovations in a single area (such as breeding, chemical inputs, or irrigation technology), future solutions are expected to arise also from the optimisation of systems, i.e. the optimisation of the interplay between system components and between those components and ecosystems. **Integrated ecological approaches** are a promising area of research and innovation; a better use of ecosystem services is expected to strengthen the sustainability and resilience of farming systems. Synergies and trade-offs between the different environmental challenges and productivity and profitability aspects have to be considered in order to create win-win situations and design pathways to innovative and resilient ecological farming systems.

Functional ecology and community ecology are key scientific disciplines that need to be further developed to support what could be called 'precision ecology'. Biodiversity and various ecosystems provide many different services to primary production, not all of which are well known. These include pollination, biological pest control, maintenance of soil structure and fertility, nutrient cycling and hydrological services. It is important to explore the functional role of biodiversity in the delivery of ecosystem services. This includes the interactions between plants and/or animals and other organisms as well as the interactions in the soil, etc. To develop agricultural and forestry systems that maximise ecosystem services, a leap in knowledge is required. This can be supported by various scientific areas, **from developing farming practices to technologies**. Ecological disciplines can be strengthened by approaches both at the molecular level (supported by the various –omics techniques) and at the landscape level. Research is also needed on new species or organisms, their cultivation and potential interactions with ecosystems and wild relatives or species, and how the outputs of multifunctional systems can be exploited in the best way.

Research is needed to underpin ecological approaches to shift from the study of individual species in relation to their environment to the study of groups of organisms or polycultures in relation to each other and their environment. It will look at optimising the use of ecosystem services and the **landscape level design of forest and agroecosystems**. More specifically, more insight is needed into the synergetic effects of combinations of ecosystem service processes, as current research mainly addresses how single service processes work in isolation. This approach would consider the full range of production systems and would require a transdisciplinary approach.

Specific types of farming systems that implement ecological approaches have developed in Europe, and these have their own research needs. These include the organic sector, which is the largest of such farming system with a dedicated regulatory framework and

[47] There is no single definition of 'landscape'. The term 'landscape' is often used to refer to processes that cover a large area, usually addressing a range of ecosystem processes, conservation objectives and land uses. A landscape is usually smaller than a territory.

[48] We use the definition in *Millennium Ecosystem Assessment on Ecosystems and Human Well-being*. 'Ecosystem services are the benefits people obtain from ecosystems. These include provisioning (e.g. water availability), regulating (e.g. disease and pest reduction), and cultural services (ecotourism) that directly affect people and the supporting services (e.g. nutrient cycling) needed to maintain other services. Many of the services listed here are highly interlinked: primary production, photosynthesis, nutrient cycling and water cycling, for example, all involve different aspects of the same biological processes'.

an action plan which calls for strengthened research.[49] Other systems also need to be considered, especially mixed farming systems (plant/animal, agroforestry, intercropping, etc.), with a view to reconsidering the role of livestock and forestry in ecological approaches. The development of new farming systems (permaculture, insects, vertical farming, etc.) should also be considered. Research developed into these specific approaches has the potential to be extended to other systems.

Collaboration with other parts of the food and non-food supply chain is necessary to develop interesting, new and creative solutions and business models especially for radical eco-innovations. Annual reports by the Eco-Innovation Observatory highlight the benefits of cooperation between the agricultural sector and other sectors like the food and beverage industry, retail and the water and waste management sector. When adopting and promoting ecological approaches, it is also important to take into account the role of consumers and end-users. The organisation of sustainable food and non-food supply chains and the governance of ecological approaches are tackled in section 2.3.2.1 "*new openings for rural growth*". In this area, transition pathways will be developed that take account of constraints and 'lock-in' effects.

Knowledge relating to agroecosystems is site-specific and evolving. Ecological approaches are knowledge-intensive and depend on combining formal and practical knowledge with modern technologies. Innovations are expected to capitalise on local conditions and provide tailor-made solutions rather than solutions with a broad application. Long-term experiments and an appropriate research infrastructure need to be developed to meet the specific needs of ecological approaches in relation to a particular landscape level and its evolution over a longer period of time (e.g. systems that include forestry). Appropriate metrics will be necessary to assess the environmental trade-offs and impacts of various systems in different geographic and time scales.

[49] Action Plan for the future of organic production in the European Union (COM(2014) 179 final).

2.3.2. Enhancing rural innovation: modernising rural territories and policies

Rural areas across the EU have undergone profound changes in the last few decades. The most pervasive ones are probably the sectoral shift and the decline of the relative importance of agriculture in the rural economies of Europe, driven largely by productivity increases across the sector. The services sector appears to be the primary job provider and one of the main drivers of economic growth in rural areas, along with upstream and downstream industries. New activities have developed, including tourism, small-scale and niche manufacturing and food production and business services. ICT developments partially solve the problem of remoteness and offer a wide range of new business opportunities.

While economic diversification away from primary production was an important objective of rural policies in recent decades, the food security agenda and the increasing demand for biomass for a variety of bio-based applications have again raised new interest in the economic opportunities related to primary production and the associated food and non-food value chains. This new interest is combined with stakeholder concerns over the capacity of rural areas to cater sustainably for all these needs while providing essential ecosystem services, amidst increasing urbanisation (and soil sealing) and the pressure on land resources caused by climate change. There are also important questions around the impact that different types of value chains or renewed urban-rural linkages could have on local development and job creation.

Evidence and knowledge can help policy-makers overcome challenges described earlier and seize new opportunities by helping them to develop the most appropriate policies and governance approaches.

2.3.2.1. New openings for rural growth

Rural areas supply food, timber, fibre, water and a range of ecosystem services and public goods. Yet society's demand for products and services based on natural resources is growing and the capacity of rural areas to match it will contribute to shaping their future economic growth and social progress. Building on a solid analysis of **territorial dynamics**, research and innovation activities under this priority can contribute to identify new avenues for rural growth in relation to **1) food and non-food value chains**, **2) the delivery and economics of public goods**, **3) other key economic sectors** such as services, infrastructure, logistics and digital activities which enable or facilitate innovation and socioeconomic development in all sectors. The focus should be on integrated and place-based approaches which look across sectors and take into account territorial assets and limitations. Activities should be **clearly impact-oriented** with strong **dissemination requirements**, in particular towards **policymakers,** informal governance bodies and local development groups who are involved in deciding on policies at different scales.

Understanding territorial dynamics and modernising policies

Exploring the conditions for **sustainable growth in rural areas** will be one cross-cutting activity under this priority. Economic policies supporting growth in rural areas reflect to some extent the underlying theoretical models that prevailed at the time they were implemented. Thus, over the decades, explanatory frameworks have switched from exogenous growth (i.e. development underpinned primarily by external factors) to endogenous growth (i.e. encouraged by an area's own endowment of resources). Current thinking acknowledges the contribution of mixed approaches which aim to harness rural area's own capital (natural, human and social) without neglecting potential support and synergies originating from outside these rural areas. In addition, policies focusing on specific sectors have given way to integrated approaches at territorial level which take account of local circumstances ('place-based approaches'). In parallel, policies designed to cope with overarching objectives (such as climate change, biodiversity, trade) have direct and indirect impacts on the primary sector and more generally on rural areas.

To really understand the dynamics of development in rural areas, research activities should capture major trends affecting rural areas both economically and socially and should differentiate between types of areas characterised by different environments and varying degrees of remoteness. These will include trends related to **demography** (ageing, migration between countries and between different areas in one country, selective migration of women and young people, lifestyles), **market dynamics** (including rural financing, market power and concentration in upstream and downstream industries), changing structures, land ownership and employment patterns (in particular in farming), **climate change**, trends in **services or digital development and their impact on attractiveness**. Research will also aim to cover the **social aspects that underpin** rural development (e.g. the role of networks, citizen's engagement in local decisions and policies). **Scenario** types of projects and **foresight activities** will be useful for establishing the impact of these trends on rural areas and policies. Greater integration of models and data could also help improve the assessment of the impact of policies on rural areas (both *ex-ante* and *ex-post*).

Attention has been placed recently on **territorial linkages** (urban-rural, rural-rural, land-sea) and their contribution to sustainable growth.[50] Some stakeholders have argued against putting too much effort into delineating boundaries between different types of territories as these are constantly changing.[51] Various aspects of these linkages can however be investigated: the analytical framework can be clarified, governance approaches which enhance synergies between rural and urban development and between economic sectors in concerned territories can be analysed and avenues for new business developments building on these linkages can be identified and up-scaled, including social innovation and regional branding. Beyond those linkages, holistic analytical frameworks can be developed, together

[50] *Rural-urban partnerships, OECD Rural policy reviews*, OECD, 2013.

[51] http://ec.europa.eu/newsroom/horizon2020/document.cfm?doc_id=10857.

[52] https://ec.europa.eu/programmes/horizon2020/sites/horizon2020/files/20150219_Workshop_Rural_Empowerment_report_final.pdf.

with the necessary analytical tools and indicators, which would allow a thorough assessment of synergies and trade-offs between sectors and biomass uses, taking into consideration the delivery of ecosystem services, circular economy approaches, job creation and added value as well as land use management. Territorial linkages should be understood in a broad sense and not only as the relationship between an urban area and its immediate periphery.[52]

Organising sustainable food and non-food value chains under changing conditions

Sustainable, diverse and resilient food systems are a prerequisite for sustainable rural growth and for food security. Research has a role to play in unravelling the links between the complexity of food systems and their efficiency, resilience and sustainability.

Food supply chains operate in an increasingly complex and dynamic environment characterised by new demands, new technologies, changing structures and cooperation modes. Food demand by consumers is evolving in terms of various quality attributes (authenticity, standards, certification, origin, healthiness, local or regional supply, etc.). Through the use of new business models, this can generate higher incomes for producers both in Europe and in developing countries (especially small-scale farmers), while keeping consumer prices affordable. Encouraging food chain competitiveness, sustainability and resilience requires an understanding of food chain dynamics (and of chain individual components) and the interactions between them and with non-food chains. All dimensions of sustainability will be investigated: **environmental** (resource management, waste reduction at various levels, climate change mitigation and adaptation, biodiversity conservation), **economic** (competitiveness, business approaches, incentives and behaviours, traceability and certification, transparency and balance of market power, distribution of added value and income along the supply chain, impact on local economy) and **social** (contribution to the quality of life and rural revitalisation, i.e. in terms of food availability and various dimensions of quality and health, jobs and working conditions, cultural aspects). Emerging approaches (such as short-supply chains, new business models) deserve attention as they may provide solutions for improving sustainability and providing territorial benefits. Cooperative and other collective approaches can for example deliver multiple benefits (increased market power, logistics, etc.). Research and innovation activities should contribute to designing appropriate business models and up-scaling them. The **role of consumers** needs to be researched as it has a strong bearing on the whole food system and how it works, in particular in the context of emerging urban food policies and urban farming, the development of regional or sustainability labels or sustainable public procurement which can impact primary production. **Drivers of sustainable consumption** need to be better understood (for example when it comes to promoting "integrated ecological approaches", as mentioned in section 2.3.1.3, or to consumption of livestock products).

The role of the **upstream industry** also needs to be scrutinised, as a provider of essential inputs (seeds and breeds, fertilisers, plant and animal health products), a driver of farm practices in particular through advice and as a provider of growth and jobs.

Similarly, **policies that shape food value chains should be analysed**, exploring how interventions could have an impact on environmental, economic and social sustainability as described above.

Farmers and foresters have since immemorial times produced non-food products, whether for **energy** (e.g. fuel wood) or **industrial purposes** (e.g. raw material for paper or textiles). However, the need to decarbonise the energy sector to respect climate change goals compounded with considerations of resource efficiency, a rapidly changing energy landscape and an **increasing interest in green chemicals and green growth** call for renewed attention to diverse uses of land and biomass driven by scientific and technological progress and the related promising markets.

Research and innovation activities in this area will address **low-carbon short-chain delivery systems for innovative and sustainable bio-based applications** (e.g. bioenergy, biochemical, biomaterials) while using a systems-based approach for the provision of biomass for all uses (food, feed and industrial applications, traditional and new uses) and preserving the delivery of other ecosystem services. Emphasis will be placed on **integrated and diverse production systems and agronomic or forestry practices to increase the overall productivity of land for food and non-food applications**. Other opportunities can be generated by growing biomass crops on less-productive or abandoned lands (while avoiding biodiversity losses) and through the use of residues, co-products and waste on-farm and along the value chains, using **resource-efficient and circular approaches**. Appropriate solutions are necessary to minimise adverse environmental impacts, such as the establishment of closed circuits of nutrients, as mentioned under section 2.3.1.1. New business processes and products will have implications for farm design, management, farm income and for food or feed availability in the agro-food chain and will require research with close connections between natural, engineering and socioeconomic sciences. Activities will focus on biomass production and **infrastructure and logistical improvement** to foster the emergence of new biomass supply chains for non-food applications while considering the sustainability of related land-use systems and integration or synergies with food systems. Innovation strategies developed at local or regional level will be complemented by cross-sectoral activities on a larger geographic scale. Research will extend to the tools, indicators and forward-looking activities which are necessary for all stakeholders to identify, implement and monitor relevant strategies, policies and legislation targeting rural areas in view of optimising the sustainable management of natural resources at territorial level and the creation of jobs and value-added in rural areas.

Better rewarding the provision of public goods

The increasing value assigned by the society to the environment, culture and heritage of rural areas can be a driver of their sustainable growth. This has materialised to a certain extent for public goods related to culture and heritage, e.g. tourism based on traditional landscapes or traditional food products. However, the situation is less favourable for most **environmental public goods** such as water and air quality or biodiversity. Delivery of these goods is widely reckoned to be insufficient and is in the focus of some of the Sustainable Development Goals adopted in September 2015. Farmers and foresters are responsible for the management of most land in the EU and, depending on practices used, can indeed be sources of a wealth of environmental public goods or can threaten them, thereby constraining the long-term sustainable growth of rural areas and the benefit from these public goods to the whole society. Research will address the main environmental public goods individually to examine specific stakeholder behaviour and market mechanisms, while also considering combined delivery and integrated approaches to tackle synergies and trade-offs between different public goods and users.

Attention will be directed to **policy and socioeconomic dimensions**, including consistency with the development, implementation and impact assessment of new policy instruments and delivery mechanisms as well as the necessary decision-making and monitoring tools. This will include, for example, progressing towards the **valuation and pricing of public goods**[53] and creation of **policy and market-based mechanisms**. Societal involvement in the development of such mechanisms will be particularly important. Potential economic spin-offs related to the delivery of public goods will be analysed along with possibilities for developing collective approaches to the provision of public goods.

Taking advantage of the digital revolution

Information and communication technologies (ICT) can partially solve the problem of remoteness and therefore bring new opportunities to develop businesses that could not be established in the past and are likely to raise rural attractiveness, in particular to younger generations, if sufficient infrastructures are in place. They offer opportunities to renew business models in the food and non-food value chains, by connecting producers to consumers. For example, setting-up innovative marketing channels, such as new types of short food supply chains, or improving logistics. They bring innovative solutions which can help to modernise the provision of services and make services more efficient for both providers and citizens in areas of lower population density. ICT can also support a greater involvement of rural dwellers in policy-making, networking and collective initiatives, thus enabling modern approaches to governance. Research and innovation activities under this priority will explore and upscale business and governance models which can boost rural economies on the basis of digital applications.

[53] See for instance the EU initiative on Mapping and Assessment of Ecosystems and their Services (MAES). Http://biodiversity.europa.eu/maes.

2.3.2.2. Enhancing the human and social capital in rural areas

The need to encourage innovation in agriculture has been repeatedly emphasised in recent years. Agricultural activity has never taken place in a static environment. Yet, in the last decades, this environment has become more complex owing to more open economic conditions and associated opportunities and risks. The same applies to forestry. Beyond agriculture, innovation in rural areas can play an important role in stimulating green and socially inclusive economic growth, mitigating geographic isolation and avoiding economic and social marginalisation. Human capital (i.e. individual skills that enable actors to perform or initiate economic activities) and social capital, i.e. the links, incentives, shared values and norms that underpin the capacity of actors to trust each other and cooperate, are essential to successful rural innovation.

Innovation has been assigned a key role by the Commission to meet the objectives of the 'Europe 2020' strategy. Horizon 2020 has consequently aligned with the objective of encouraging innovation. European Innovation Partnerships (EIPs) have been established in various areas to accelerate research, development and market deployment of innovations to tackle major societal challenges, pool expertise and resources and boost the competitiveness of EU industry. Among these, the EIP 'Agricultural productivity and sustainability' (EIP-AGRI) tackles innovation in agriculture and rural areas and is implemented through both Horizon 2020 and the rural development arm of the CAP. In broad terms the EIP-AGRI aims at fostering all three dimensions of sustainability of the farming activity.[54]

The complex environment outlined above does not call for simple solutions developed across the board but for a variety of solutions adapted to a variety of contexts and regional circumstances. Hence, the so-called linear approach, whereby solutions developed by knowledge centres were transferred and implemented uniformly by farmers with the support of advisory services and relevant policies, is no longer sufficient.[55] Dealing with complexity requires the harnessing of all available knowledge sources, including tacit knowledge at farm and business level and requires the involvement of all relevant actors (farmers, foresters, cooperative and industry, advisors and knowledge brokers, etc.) in a process of knowledge co-creation and appropriation. This is what we refer to as the **interactive innovation model**.

Activities under this priority will aim to support sustainable growth in rural areas by encouraging innovation. They

[54] COM(2012) 79 final.

[55] See for instance Commission staff working paper, impact assessment of the Common Agricultural Policy towards 2020 - Annex 7: Research and Innovation (SEC(2011) 1153 final/2).

will have two main strands. The first will investigate the **skills, human and social capital** of farmers and rural dwellers which are essential to enable them to develop their activity in the complex environment referred to above. The second will look at the **knowledge and innovation systems** and aim to improve their delivery.

The dynamics of economic activities in rural areas are heavily dependent on their **social and human capital**. Enhancing innovation implies, on the one hand, understanding the values that can encourage or constrain social capital (such as attitudes towards networking, gender values, inclusion of younger generations, equal opportunities, etc.). This necessitates knowing better who the actors (farmers, entrepreneurs, rural dwellers) are and will be in the future and what their current and future needs are. On the other hand enhancing innovation implies providing the necessary hard and soft (e.g. entrepreneurial) skills. This is why **education and training** need to be at the heart of any endeavour to boost knowledge and innovation in rural areas. This goes well beyond initial education and training as skills increasingly need to be maintained and updated to keep pace with societal change.

Horizon 2020 and its succeeding Framework Programme will be used to provide knowledge on the functioning of the **knowledge and innovation systems** with the objective of improving their delivery in rural areas, including recent approaches such as the EIP-AGRI. This will cover all parts of the systems (science, education and training, advisory services), categories of actors (knowledge users, intermediaries and researchers, networks, clusters), types of innovation (technological, social, organisational, etc.) and policies (CAP, research and innovation and education policies). Encouragement to participatory approaches, systems-based approaches involving interdisciplinary or transdisciplinary work will only deliver if the research systems provide the necessary facilitating environment. Research will cover such aspects as the integration of new demands and technologies; the impact of participatory research; skills and rewarding of participatory research and more broadly evaluation of researchers.

Attention will not be limited to innovation at primary production level but will extend to other actors in the supply chain or, more generally, in the rural economy. Links with innovation processes in urban areas and the ability of policymakers to properly deal with innovation will also be investigated. As approaches to innovation are strongly influenced by social and economic circumstances, and differ widely across the EU, benchmarking and the exchange of experience between national- and regional-level knowledge and innovation systems in the EU will be encouraged. Beyond European borders, the capacity of knowledge and innovation systems to facilitate convergence between research and practice to better respond to global challenges should be properly looked at.

CHAPTER 3

How will the strategy be implemented?

3.1. Strategic programming and programme management

The main priorities of the strategy will be further specified in terms of developing more specific lines of action. These will feed into the overall Horizon 2020 strategic programming for 2018-2020 and of its successor and be part of the stakeholder consultations that will take place throughout the process. These should take account of the EIP-AGRI and the research and innovation agendas of relevant European Technology Platforms.

The implementation of the strategy through the various calls will require close monitoring of the funded activities (in particular from the various parts of Horizon 2020) and their mapping against the strategy's set objectives.

Furthermore, the strategy will need to be reviewed periodically in the light of findings and recommendations of new foresight reports (from the SCAR and others) and stakeholder consultations.

3.2. Encouraging synergies with Member State research and innovation activities and the development of the European Research Area

Although resources allocated to agricultural research (and more generally to the bioeconomy) have increased significantly in Horizon 2020 in comparison with the previous programme for 2007-2013 (Framework Programme 7), they still amount to a fraction of Member State investments[56]. Building the **European Research Area** (ERA) is a key objective of Horizon 2020[57]. Within this, encouraging synergies between Member States and between Member States and the

EU Framework Programme is essential for impact and efficiency. ERANETs, Joint Programming Initiatives (JPIs), Article 185 initiatives can contribute to coordination and integration of research between Member States and the Framework Programme to different extents. Other instruments may also be used to respond to these objectives, for instance the European Joint Programmes (EJPs). Synergies will be developed with relevant Joint Programming Initiatives such as FACCE (agriculture, food security and climate change) with a view to strengthening the European integration of their programmes.

Building the ERA is a long-term process. It still stands at an early stage with limited alignment and synergies between national programmes. A process of reflection needs to be engaged with Member States with the objective to strengthen the ERA.

[56] A rough comparison can be made through GBAORD data from Eurostat. They suggest that EU investments correspond to around 8% of Member State spending. Yet it is important to remember that the nature of what is being compared is not exactly the same: EU investments are project investments whereas Member States investments also have to cover the running costs of the research and innovation activities. In addition, the multinational nature of Horizon 2020 activities offers added value to activities implemented at national level. Finally, taking account of research and innovation activities financed through the Structural Funds, the share of EU-financed agricultural research may well increase to about 15% of Member State investments.

[57] COM(2012) 392 final.

The aim of encouraging coordination and synergies in research needs to be carefully balanced with the objective of involving as many Member States as possible in the various activities of Horizon 2020. Some Member States may find themselves unable to take part in some coordination activities (for instance ERANETs) due to resource constraints, despite having a research capacity that could add value to these activities.

The Standing Committee on Agricultural Research and the Programme Committee are the relevant places for discussions of strategic aspects relevant to research and innovation policies.

The European Regional Development Fund provides significant support to research and innovation in Member States at the regional level[58] within Research and Innovation Strategies for Smart Specialisation (RIS3 strategies) developed at regional level. As part of these strategies a significant number of regions are investing in the agro-food sector. In addition, infrastructures and other actions are financed under Thematic Objective 1 of the Common Strategic Framework. The challenge lies in coordinating research and innovation efforts across the different policies.

3.3. The international cooperation dimension

International cooperation is a core feature of the EU Framework Programme. Participation is open to entities from around the world (with automatic funding for developing countries).

International cooperation has a role to play in boosting the **competitiveness** of European economy and the capacity of the European research and innovation system itself. Moreover, international cooperation can make a strong contribution to supporting the EU's external policy dimension and ensuring coordination and leveraging effect in addressing challenges that can better be tackled internationally, not least because of the scale of necessary resources.

EU agriculture and food systems contribute to **food security** not only in the EU but also at a global level. Demographic, dietary and income trends, climate change and environmental sustainability and domestic trade and food distribution policies are perceived as the major drivers that shape current and future food security. Most of these issues have an obvious **global dimension**. Therefore, in line with the strategy for **international cooperation** in research and innovation,[59] international activities are an integral part of this strategy. This means that the EU will strengthen its dialogue and cooperation with key international partners[60] and regions (e.g. Africa, China, the Mediterranean region) and with

[58] Regulation (EU) No 1301/2013 of the European Parliament and of the Council of 17 December 2013.

[59] COM(2012) 497 final.

[60] In particular G-20 discussions on agricultural research as part of the Meetings of the Agricultural Chief Scientists (MACS). Both G-7 and G-20 have assigned a primary role for agricultural research to foster sustainable food production and food security.

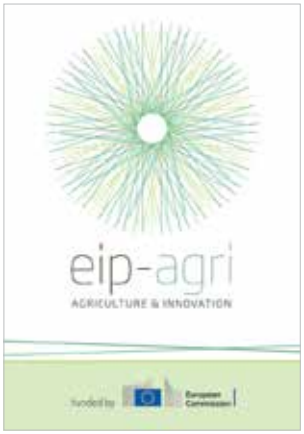
international organisations,[61] the private sector and global initiatives with a view to building a critical mass and developing synergies to tackle global challenges. The recently adopted SDGs will be guiding objectives in multilateral and bilateral cooperation, in particular SDG 2 (sustainable food and nutrition security), SDG 12 (sustainable consumption and production patterns), SDG 13 (climate change) and SDG 15 (ecosystems and biodiversity).

Activities related to **agricultural research for development** will aim to achieve wider EU development objectives and complement and establish new synergies with other investments made by the EU in this area, taking into account the lessons learned from previous and ongoing cooperation. Key initiatives will focus on sustainable agricultural production and on food security in particular in Sub-Saharan Africa and in the Mediterranean region. Coherence and synergies will be sought with DEVCO's approach to agricultural research for development.[62]

At multilateral level, activities will be sought in key areas that help support sustainable agriculture and food security, for instance animal and crop health, sustainable and ecological intensification, genetic resources or sustainable forest management. Boosting resilience and dealing with climate change will also be given due consideration. Supporting flexible platforms such as the one that is proposed on animal health under the Horizon 2020 work programme 2016/2017[63] will contribute to implement international cooperation. Complementarity and synergies will be sought with the activities of the CGIAR and initiatives such as the Belmont Forum[64] and Future Earth[65].

To a certain extent, ERA instruments such as ERANETs, JPIs, EJPs, Article 185 initiatives[66], are open to international cooperation. Additional tools for international coordination include International Research Consortia (IRCs), genuinely multilateral soft coordination mechanisms for research funders (with a focus on common objectives, coordinated research activities and concrete outputs). These tools are not EU funding instruments, but the Commission has been active in setting up and contributing financially to several of them primarily in the field of human health. Such IRCs or other appropriate forms of structured international collaboration will be considered in relevant areas.

3.4. Boosting the implementation of research and innovation



With the EIP-AGRI, the interactive innovation model is set in motion by a variety of measures or instruments under the CAP (at local and regional level) and Horizon 2020 (at transnational level). Operational Groups are the cornerstone of the EIP-AGRI under the CAP and support the development of innovations by groups of relevant actors. With Horizon 2020 the focus is set on the one hand on the implementation of the so-called **multi-actor approach** (MAA) in collaborative projects, aiming to establish a process of **genuine co-creation and implementation of knowledge** involving the concerned actors (e.g. farmers, foresters, industry, product users or consumers). A substantial part of topics under work programmes 2014/2015 and 2016/2017 involve the MAA and this approach will be continued (with any necessary adjustments) in the coming years. On the other hand, **knowledge exchange** should be facilitated by providing support to transnational networks: thematic networks that investigate particular sectors or issues and networks of experimental and demonstration farms. These networks strengthen connections between the relevant actors and facilitate the inventory and use of knowledge as well as the collection of tacit knowledge. They also provide inspiration for the actors, stimulate peer-to-peer exchanges and strengthen long-term connections and mutual trust between rural actors.

Access to past and current framework programme project results needs to be facilitated for all potential uses (innovation, further research, policy work, etc.). As indicated in section 2.2.3, e-infrastructures could play an important role in facilitating access to produced knowledge. In addition, appropriate interfaces are necessary to strengthen connections between evidence producers and evidence users for better policymaking.

The implementation of knowledge and solutions on the ground is highly conditional upon the **feasibility**

[61] E.g. the Consortium of International Agricultural Research Centres (CGIAR), the FAO, the Global Forum for Agricultural Research (GFAR), the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM).

[62] *Research and innovation – Food and nutrition security / sustainable agriculture*, Directorate General for International Cooperation and Development, European Commission, 2014.

[63] See topic SFS-12-2016 'Support for international research on animal health'.

[64] http://www.belmontforum.org/

[65] http://www.futureearth.org/

of proposed solutions. This aspect needs to be better mainstreamed into research and innovation activities.

3.5. Leaving more space for new approaches and technologies

Mechanisms need to be found so that enough space for new approaches, including social and economic innovation, is provided. A possible route could be to explore whether an instrument as Future and Emerging Technologies (FET) could be implemented in agricultural research with a bottom-up approach for Technology Readiness Levels (TRLs) 1-4[67] in order to support ground-breaking solutions.

3.6. Developing synergies with private sector research

Involvement of the private sector will be encouraged so as to increase the leverage of Horizon 2020 investments and to encourage the development of new technologies that help meet sustainable primary production objectives. In addition, the private sector has a significant role to play in the interactive-innovation model, which is supported by Horizon 2020 and the CAP (via the EIP-AGRI). Moreover, the private sector devotes most of its research and innovation effort to areas where there is a short- or medium-term return on investment. However, businesses may need to collaborate with public research on certain long-term projects, especially if they do not have the necessary in-house expertise or knowledge.

Creativity from small players will need to be actively incentivised. Small and medium-sized enterprises (SMEs) should be given due attention owing to their strong needs for research and innovation and low own capacity to finance it. This is particularly true for the food sector, which hosts a large number of SMEs. Different instruments will be explored in addition to the Horizon 2020 SME instrument. In particular, the role of financial instruments in helping start-ups and SMEs to develop new technologies and approaches should be explored (e.g. the biocontrol industry, ICT in agriculture, animal health, etc.).

[66] Article 185 of the Treaty on the Functioning of the European Union (TFEU) enables the EU to participate in research programmes undertaken jointly by several Member States, including participation in the structures created for the execution of national programmes.

[67] Technology readiness level, measured on a scale from 1 to 9 with 9 being the most mature technology.

Notes

NOTES

Designing the path

A **strategic approach** to EU agricultural **research & innovation**

Brussels, Charlemagne building
26-28 January 2016

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