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A strategic approach to EU agricultural research and innovation

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Contents

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 became a lower priority in high income countries in past decades compared to other areas[3]. Its importance was brought back to the attention of societies and policy makers in the late 2000s with the agricultural commodity price surge of 2007/2008 and concerns over long-term food security arising from long-term agricultural projections made by 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 a renewed interest in agricultural research and its potential to ensure environmental and basic societal needs in the context of evolving challenges as described in the following.

Research activities are expected to address immediate problems and at the same time anticipate future needs. Today's research will guide tomorrow's solutions and approaches in farming. Embedding research and innovation activities in a long-term strategy[4] will help identifying strategic areas of short-, medium- and long-term interest, thereby improving their overall coherence, sequencing and impact. A long-term view on research questions and investment is particularly needed considering the time lag between the initiation of research, delivery of results, their uptake by users and translation into mainstream practice. In agriculture this process can take decades[5] and is further complicated by the fact that proposed solutions 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.

By laying down strategic priorities for agricultural research in Europe it will be possible to better coordinate the activities of different funding bodies and foster synergies between major research programmes of the EU Member States and with players outside the EU. Joint efforts are expected to provide a solid basis for sustained investment in agricultural research with the aim of building critical know-how and capacities over a longer period of time.

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[1] See for instance Alston J. (2010) "The benefits from agricultural research and development, innovation and productivity growth" (OECD)

[2] CGIAR publication (2011): Measuring the Environmental Impacts of Agricultural Research: theory and Applications to CGIAR Research.

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

[4] See "Sustainable food consumption and production in a resource-constrained world" – third SCAR foresight exercise (2011).

[5] INRA (2014) "Analyse des impacts de la recherche agronomique publique". Alston *et al.* (2009) – "The Economics of Agricultural R&D", Annual Review of Resource Economics, 1, p.537-65 (2009) – estimate the average time span at 30 years.

Horizon 2020 is already well engaged with work programme 2014/2015 currently under implementation and work programme 2016/2017 published in October 2015. The strategy is meant to be an input in programming the remaining three years (2018 to 2020) and in guiding agricultural 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.

Food security[7]

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

FAO has projected a need for an increase of agricultural production by 60% in 2050 compared to 2007 to meet the projected demand for food and other uses[9]. 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). However, past growth took place with lower constraints on the use of resources and yet limited effects of climate change. In particular, production growth will have to be achieved with more stringent constraints on water availability and with limited potential 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 are the ones with the highest projected population growth by 2050 (in particular in Africa), current

[6] In this paper food system refers to the processes that describe how food from a farm ends up on our tables, how it is consumed and disposed. The processes thus include production, processing, distribution, consumption and disposal. Food supply chains are the main building blocks of a food system.

[7] We use the FAO definition of food security throughout the document: "***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 instance "Global Food Security 2030", European Commission, Joint Research Centre, Foresight Series (2015).

[9] FAO (2012) "World Agriculture towards 2030/2050, the 2012 Revision". According to the FAO, global annual production growth has been 2.2% in the period 1961-2007. The reduction of the rate of growth of agricultural production in the coming decades to about 1.1% per year on average would follow the deceleration of demand growth owing partly to the slowdown of population growth (annual growth of projected demand stands at 1.1% in 2007-2050 against 2.2% in 1970-2007). Nearly 90% of the increase in production would originate from developing countries, this would raise their share in world agricultural production from 67% in 2005/2007 to 74% in 2050.

production levels stand well below their potential, therefore raising **agricultural productivity in a sustainable manner** is necessary. Notwithstanding changing global circumstances, the long-term projections of supply and demand in most developed countries, including in the European Union suggest growth rates of supply which are within reach to ensure food security. The critical issue in Europe is therefore more to boost all dimensions of the sustainability of production, yet without underestimating the necessity to maintain a sufficient and dynamic production basis in a more uncertain world[10].

Although total food production at global level could theoretically feed the world's population, 800 million people nevertheless suffer from chronic under-nutrition[11], of which three-quarters live in rural areas in developing countries and depend to a large extend on farming activity. The critical dimension of access to food should therefore not be overlooked. At the same time there is an upward trend of **malnutrition** in both developing and developed countries, imposing large costs to societies. Sustainably increasing production will be necessary 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 all food produced[12], hence reducing waste is a lever that needs to be actioned.

Environment and climate change

Natural resources, such as soils, water and biodiversity face strong pressures partly due to inappropriate practices and overuse[13]. The State of the Environment Report of the European Environmental Agency shows[14] that agricultural activities have a significant impact on the management of natural resources. 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 (GHG) emissions including more than half of the non-CO_2 gases[15]. Globally, agriculture and forestry are the source of 24% of emissions, including

[10] It should not be forgotten that agricultural productivity varies quite significantly across and within Member States and shows sizeable potential growth in several of them. In addition the plateauing of crop yields observed in Europe in the last decades, partly due to climate change, shows the necessity to maintain or further increase yields and justifies sufficient investments in breeding.

[11] FAO (2015), The State of Food Insecurity in the world 2014

[12] FAO (2013) Food wastage footprint, impact on natural resources, summary report

[13] See UNEP, Global Environmental Outlook, GEO-5 (2012). In the case of the EU, several publications of the European Environment Agency 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 ton / 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 2015. Http://www.eea.europa.eu/soer

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

through tropical deforestation[16]. The agricultural sector, together with forestry, will have to contribute to the reduction of GHG 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 is increasingly impacted by threats and shocks which are mostly attributed to climate change (for instance a higher occurrence of extreme weather events) and to plant and animal diseases, as well as economic factors (e.g. price volatility). Climate change and water scarcity contribute also to loss of agricultural land which exacerbates pressure on remaining agricultural land. Strengthening the **resilience of farming systems** (and beyond of food and non-food systems) is therefore necessary[17] to both cope with shocks and to adapt to changing climatic conditions.

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

Growth and jobs in rural territories

The 12 million EU farms provide full-time equivalent jobs to 9.7 million persons and generate €160 billion of value added[18]. The sector has to meet consumer demands within a system which is characterised by **concentration trends** (upstream and downstream) and increasing **competition on global markets**. The sector is still characterised by fragmented structures and a producer income level which remains on average significantly below the rest of the economy. The sector is facing a significant structural adjustment (decreasing number of farms, aging of farmers, development of salaried work, diversification of activities, etc.). **Economic viability** of farming and attractiveness to the younger generation are a pre-requisite for food security. On-farm working conditions are evolving constantly and **social conditions** of the farming activity deserve sufficient attention.

Primary production interfaces with upstream and downstream sectors which both contribute significantly to jobs and growth creation[19]. Agriculture together with the forest-based sector, is also a major producer of biomass for other uses than food or feed, such as biofuels, biochemicals and biomaterials. It is an important contributor to the

[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 SCAR fourth foresight "Sustainable agriculture, forestry and fisheries in the bioeconomy – A challenge for Europe" (October 2015)

[18] Sources: Eurostat data, elaboration DG AGRI. Number of farms and employment concerns 2010, value added is an 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] 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).

bioeconomy[20]. New value chains offer additional outlets for agricultural production and activities to the rural economy shifting from fossil-based to bio-based economy. Solutions to seize these opportunities could be developed with the objective to guarantee sustainability by avoiding additional pressure on resources.

One cannot forget the **territorial dimension** of agricultural, forestry and related upstream and downstream activities. Rural areas, which still account as a whole[21] for 55% of EU jobs and 46% of gross value added, are going through a period of profound economic, demographic and institutional transformations. Globalisation, decentralisation, urbanisation, migration trends and the emergence of new product and service markets pose new challenges and opportunities to them. Rural areas are endowed with various types of assets (e.g. natural resources, cultural resources, etc.) which can contribute to foster growth and reduce gaps with other regions. Despite sustained growth in rural areas, there is indeed a persistent gap with urban and intermediate areas: in terms of GDP per capita predominantly rural regions stand at 70% of the EU average in 2010[22]. Recent research has however highlighted positive trends in rural growth[23] and a large heterogeneity among rural areas, with some areas growing faster than some urban areas, whereas others decline. Fostering **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 European Union. It aims to strengthen EU scientific and technological bases in particular by encouraging the Union to advance towards a knowledge society and to become a more competitive and sustainable economy. Horizon 2020 has been assigned a central role to support 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 policies by providing a sound evidence-base. As part of the Societal Challenge "Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy" of Horizon 2020 (so-called Societal Challenge 2), agricultural research and innovation interfaces and provides support to a range of EU policies, from the Common Agricultural Policy (CAP), the EU Forest Strategy[24],

[20] The bioeconomy encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy (see COM(2012) 60 final).

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

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

[23] OECD, 2013 [include precise ref]

[24] COM(2013) 0659 final

international development, health, environmental policies to climate action or waste reduction[25].

Support by research to policies takes obviously into account their evolution in time. For instance, for agricultural and forestry research the following policy initiatives will be important: the Energy Union Package adopted in 2015, results from COP 21 conference in Paris, the EU 2030 climate framework, the package on circular economy, the review of the bioeconomy strategy, the mid-term review of the biodiversity strategy, and of course the future CAP.

The Strategy will contribute to the implementation of the Sustainable Development Goals adopted in September 2015, for both domestic and external policies of the EU. Most of the targets of Goal 2 "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" are relevant for agricultural research[26]. The strategy can also contribute to attain the following SDGs:

- SDG 12 "Ensure sustainable consumption and production patterns"
- SDG 13 "Take urgent action to combat climate change and its impacts
- SDG 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 last years, synergies between Horizon 2020 and the CAP have been strengthened:

- Agricultural research and innovation in Horizon 2020 aims at supporting 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[27];
- Important for these overarching goals is to bridge the gap between theory and practice to allow agriculture and rural areas to become more sustainable and competitive and capable of adapting to emerging challenges. Innovation – together with climate change and environment – is a cross-cutting objective within Rural Development. The EIP-AGRI rests on both policies to foster innovation on the ground and support a knowledge-based agriculture. In

[25] 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) and repealing Decision No 1982/2006/EC (Official Journal of the European Union, L 347, 20 December 2013): "agricultural research and innovation interfaces and provides support to a range of EU policies: the Common Agricultural Policy (CAP), Environmental policies, the Union's innovation and industrial policies, external and development aid policies, plant health strategies, animal health and welfare strategies, the European Climate Change Programme, regulatory frameworks to protect the environment (e.g. Soil thematic strategy, the Union 2020 biodiversity strategy), health and safety, to promote resource efficiency and climate action and to reduce waste".

[26] "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."

[27] COM(2010) 672 final

particular it provides support to rural actors to exchange knowledge and join forces to solve particular problems.

As EU policy frameworks relating to agriculture and food evolve, there will likely be an increasing need to invest in the knowledge systems underpinning these policy frameworks.

The long-term strategy for agricultural research and innovation will be an important component of the **European Food Research Area,** to be launched in October 2016, which will bundle all efforts in the field of food security.

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

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

2. WHAT PRIORITY AREAS FOR RESEARCH AND INNOVATION?

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

The boundaries of the long-term strategy for EU agricultural research and innovation need to be clearly outlined. The document does not cover the full scope of Horizon 2020 Societal Challenge 2. It focuses on land-based primary production, centred around agriculture and forestry, but extends to food and non-food chains and the rural economy. It considers relevant interfaces with other compartments of Societal Challenge 2 (for instance Marine research) and with other parts of Horizon 2020[28].

2.2. Cross cutting issues

2.2.1. Systems approach, interdisciplinarity and transdisciplinarity

The necessity to adopt a **systems approach** towards research has been emphasised in several papers[29] (e.g. last two SCAR foresights of the Standing Committee on Agricultural Research - SCAR -, the International assessment of agricultural knowledge, science and technology for development - IAASTD - and recently by the Expo 2015 EU Scientific Steering Committee). Meeting the challenges facing the agricultural and food and non-food systems implies working in an integrated manner so that proposed solutions are fit for both the problem they address and the main objectives pursued regarding the system as a whole, for instance the food system. In addition such an approach should inform on the impact of the various actors on the other parts of the system, for instance the role of consumer preferences in the food chain. This requires in particular fostering interdisciplinary (Expo 2015 EU scientific steering committee) or even transdisciplinary (4th SCAR foresight) approaches. In addition, most papers insist on the imperative to foster implementation of research results and innovation on the ground.

Systems approach will be implemented 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. This will be done at two levels: at project level the wider context in which projects take part (food chain for instance) will be taken into consideration. This is already a practice, as a series of projects from Horizon 2020 work programme 2014/2015 and topics from work programme 2016/2017 extend their activities beyond the primary

[28] For instance ICT (in 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).

[29] "Agriculture at a crossroads, International assessment of agricultural knowledge, science and technology for development", IAASTD (2009); Third SCAR foresight exercise "Sustainable food consumption and production in a resource-constrained world" (2011); Fourth SCAR foresight "Sustainable agriculture, forestry and fisheries in the bioeconomy – A challenge for Europe" (October 2015); "Global Food Security 2030", European Commission, Joint Research Centre, Foresight Series (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).

sector into the food and non-food supply chain. In addition, **interdisciplinary**[30] and **transdisciplinary**[31] approaches will be encouraged whenever relevant.

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

2.2.2. ICT as an enabling technology for agricultural 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 through e.g. precision farming, ICT has an immense potential to support many elements of the rural economy, from food and non-food supply chain management to new business development[32]. 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 opened by the internet of things and big data approaches, taking into account unresolved issues such as data ownership and user rights. ICT will also be an enabler in the process of research (generating, using, sharing data, crowd science, etc.).

2.2.3. Enabling science and infrastructures

Public funding is important for basic research and infrastructures, domains where private funding is more difficult as it tends to focus on applied research.

Enabling science has a key role to play for fundamental understanding of biological processes, from molecular biology to cells, organisms, populations and ecosystems. It ranges from genomics to statistical modelling, benchmarking, pilot systems facilitating 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 establish targets and allow for monitoring and comparing agricultural and forest resource efficiency and environmental footprints of management options and farming systems at various levels including the global one.

A reflection needs to take place together with Member States on necessary infrastructures to facilitate research at the European level. Topics of interest include e-infrastructures, to facilitate data use and sharing and to curate research outputs, infrastructures linking experimental and demonstration farms, etc.

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

[31] 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.

[32] 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. Socio-economic research and support to EU policies

Research, in particular socio-economic research, plays a crucial role to underpin the design and implementation of efficient and effective **policies** which impact rural territories and food and non-food systems and which are not necessarily addressed in the priority areas described below. This concerns a range of policies, not just the CAP, and requires attention at various scales: from the individual to the society and from local to global dimensions. In particular, research has a strong role to play in contributing to the development of the analytical tools which are necessary to assess the concerned EU policies. In view of the various objectives that apply to policies targeting agriculture, forestry and the rural economy at large (economic, environmental, etc.) it is important that these analytical tools are able to grasp a larger range of issues at various scales. Socio-economic research needs to be mobilised to assess the economic sustainability of the various activities relevant in rural areas, including the farming activity, 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, socio-economic research will play a key role to establish appropriate interfaces between research and society. Societal engagement in research and innovation is a particularly important issue.

2.3. Priority areas

Five priority areas for research and innovation have been identified clustered in two headings.

Heading 1: creating value from land: sustainable primary production:

- Resource management (notably soil, water, biodiversity)
- Healthier plants 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 in several priorities but from different angles. Research topics will take this in consideration and – as necessary – will cut across several priorities so as to integrate the aspects for which this is important.

In the first cluster, the third priority on integrated ecological approaches capitalises on the ones on resource management and on healthier plants and animals. This priority area aims at looking 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.

2.3.1. Creating value from land: Sustainable Primary Production

Agriculture has evolved remarkably over thousands of years giving rise to a range of often highly specialised and high yielding 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[33]. The environmental and social dimensions of agricultural production are put under further scrutiny as a result of increasing evidence of the links between food and human health.

The present section focuses on resource management, plant and animal health and underpinning ecological approaches as these three areas lend themselves well to illustrate the agriculture-food-environment interface. They are described to pin down 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 said to be already used in excess of current Earth capacity[34]. Pressures on natural resources are further accentuated by the effects of increased environmental variations related to climate change to which agriculture is also contributing.

Research on agricultural resource use will aim at ensuring long-term productivity of the sector as well as reducing its adverse impacts on ecosystems and human health. These goals will be pursued by tackling 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 adaptation and resilience and strengthen contribution to climate change mitigation. The livestock sector is a prime area of interest as regards opportunities to reduce GHG emissions in agriculture.

A research agenda to address 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 larger spatial scale, cooperation between farms as well as rural-urban interactions will provide opportunities for linking urban and agricultural resource flows (e.g. water, waste, see also section 2.3.2 on rural innovation). These synergies are likely to expand as the

[33] 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

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

concept of a **circular economy** is gaining momentum[35]. In the area of agriculture its implementation 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.

Technology-wise, 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 (time and space-wise), and improve their environmental performance. The combined use of prediction models and monitoring sensors for example, can support precision irrigation and nutrient management practices. 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[36]. 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 management of animals as well as to reduce emission of GHG, for example through precision feeding, monitoring of physiology, 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.

Land, soil, water and genetic resources are seen as a main focus for research under this priority as they provide the very basis for 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 fostering measures that increase soil carbon content as well as soil biodiversity and reduce soil erosion. Crops interacting effectively with the soil food web will contribute to fully exploiting the productive potential of soils. Next to adequate management practices such as crop rotations, fertiliser application and tillage practices, adapted machinery and tools for monitoring the status of soils are required to support changes in land cultivation and management. Knowledge and tools generated 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 foster the function of soils as carbon and nitrogen sinks, thereby supporting the role of agriculture and forestry in climate change mitigation as well as in combating desertification and land degradation.

[35] The Commission is aiming to present a circular economy strategy late in 2015, to transform Europe into a more competitive resource-efficient economy; http://ec.europa.eu/environment/circular-economy/index_en.htm.

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

Knowledge and innovations are further sought in the area of **agricultural water use and management** with the aims to reduce the heavy reliance on this increasingly scarce resource[37] and to reduce water pollution from agriculture. Research will tackle on-farm water management by means of exploiting the genetic variation of plants and animals (e.g. increasing water use efficiency by improving plant root traits), increasing knowledge on interactions between genotype, environment and management, support 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. It will also seek to maximise 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, is covered under section 2.4.2 "Enhancing rural innovation".

Genetic resources underpin agricultural production and are considered as a prerequisite for ensuring food security under a range of (changing) environments. Current food and non-food systems rely heavily on a small number of crops and breeds[38] and the preservation of genetic resources is seen as insurance to sustain breeding activities and cope with future demands in farming, forestry and consumption. Research activities will promote *in-situ* and *ex-situ* conservation of plant and animal genetic resources and enhance the connection between these two. Efforts are required to support the genotypic and phenotypic characterisation of a wide range of genetic resources, also taking into account the potential of so far underutilised plant and animal breeds. Activities will also aim at improving information and access to genetic resources and support their use by breeders, farmers, forest owners and managers and in both food and non-food value chains. For this, adequate facilities, information tools and standardised methods need to be in place, also in view of better connecting the various stakeholders involved in the management of genetic resources.

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 (e.g. Xylella) or endemic (Campylobacter). These pests and pathogens can have serious impacts on human health and food safety either directly (zoonoses), indirectly (chemical residues) or both (anti-microbial resistance). In the animal sector, diseases are detrimental to animal welfare and are key to improving overall production efficiency and thereby decreasing the carbon footprint of production systems.

[37] 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

[38] 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

Plant and animal production are under mounting pressure due to the increasing number and frequency of new and re-emerging pests and pathogens as a consequence of globalisation, trade development and climate change which increase their potential for establishment and spread.

European agriculture needs to be granted sufficient means to cope with the above-mentioned threats to ensure food security and feed supply, a smooth functioning of the single EU market and ensure consumer confidence in food by mitigating potential risks to plant, animal and human health (including food-borne zoonoses). This extends largely beyond fighting against pests and diseases to developing appropriate practices that prevent their occurrence.

Plant and animal pests and diseases can have a multifactorial origin and result from inappropriate production conditions. In that sense, **animal and plant health has to be considered through a systems approach** which includes the various components of production (breeding, management, animal nutrition) and its environment (farming practices, production systems, environmental impacts). 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[39]. According to 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"[40] and focuses not only on transmission disruption but also on drivers of disease emergence. A broader concept refers to attaining optimal health for people, animals and the environment. This would go beyond infectious animal diseases and may include chemical substances, plant health, etc.

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 (with)in a farm or an establishment or territory, 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 or approaches, including environmental ones, contributing to prevent or control affected animals and plants will need to be considered. As regards livestock, health and welfare indicators should be developed. 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; assessment of sources, burden and impact of pests and diseases for developing cost-

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

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

effective surveillance and control in plants and livestock; forecasting tools making use of ICT developments, using big data combined with autonomous farming systems; innovative approaches to treat diseased animals and plants.

Reducing the uses of pesticides in the plant sector and **antimicrobials** in the animal sector is needed for human health (problems of pesticide residues, risks for pesticide users, antimicrobial resistance), animal health (antibiotic resistance), environmental considerations (e.g. water pollution, biodiversity, wild pollinators) and long-term sustainability of the sector. In the plant sector, implementation of Regulation (EC) 1107/2009[41] results in the reduction of the available active substances which requires alternatives to be found. The slowdown of the development of new antimicrobials for human health constrains the availability and use of antimicrobials for animals, in particular critical molecules. Ambitious research would be necessary to provide producers with alternative approaches allowing a reduced use of pesticides and antimicrobials and to support the implementation of the Sustainable Use of Pesticides Directive (SUD), including integrated pest management (IPM)[42] and the Action Plan against rising threats from Antimicrobial Resistance[43]. This research would be all the more necessary in small sectors, which have been rather neglected by public and private research: this concerns in particular the so-called minor crops as well as marginal animal sectors (such as beekeeping, small ruminants).

Dealing with **emerging risks** is a priority and preparedness for them is challenging. In a number of cases, emerging diseases in animals are zoonotic and outbreak is often diagnosed first in humans. Vector-borne diseases are of particular importance in animals not least because of climate change that increases the geographical area of prevalence of vectors.

Specifically in the livestock sector, the relation between **animal feed(ing)** and health needs to be further investigated. In addition, the possibilities to improve **animal welfare** through more appropriate management of animals need to be further explored.

Strengthening **basic research** is necessary in a range of areas; biology/ecology of pests and pathogens, animal/plant genetic make-up and biology (not least on microbiome and immunology), host-pathogen interactions (including plant-soil-microbe interactions), the connection between genotype and phenotype, system biology, biomarkers, epidemiological modelling.

[41] 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)

[42] 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).

[43] Communication from the Commission to the European Parliament and the Council "Action Plan against threats from Antimicrobial Resistance" (COM(2011) 748)

2.3.1.3. Integrated ecological approaches from farm to landscape[44] 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 concerning the environmental concerns closely related to the primary production (biodiversity, habitats, water quality and quantity, climate change, air quality, etc.).

A deeper understanding of ecological principles is changing views on the functioning of primary production systems and will potentially allow taking advantage of ecosystem services[45] for the benefit of sustainable production. While advances in agriculture have often resulted from innovations on single components (such as breeding, chemical inputs, irrigation technologies), future solutions are expected to arise also from the optimisation of systems, i.e. the optimisation of the interplay between their components and between those components and the 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 design win-win situations and 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 agricultural production, not all of which are properly known. This includes pollination, biological pest control, maintenance of soil structure and fertility, nutrient cycling and hydrological services. It would be in particular important to explore the functional role of biodiversity in the delivery of ecosystem services. This would include the interactions between plants or animals and other organisms as well as the interactions in the soil, etc. To develop agricultural systems maximizing services from ecosystems, a knowledge leap is necessary which 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 platforms) 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 agro-ecosystems**. More

[44] There is no single definition of landscape. Landscape is often utilised to refer to processes that cover a large spatial scale, usually addressing a range of ecosystem processes, conservation objectives and land uses. This is usually smaller than a territory.

[45] We use the definition provided within the report of the 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.

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 considers production systems in their diversity and implies the involvement of various research areas in a transdisciplinary manner.

Specific types of farming systems implementing ecological approaches have developed in Europe which have their own research needs to be catered for. Among these, the organic sector is the largest one, with a dedicated regulatory framework and an action plan which calls for strengthened research[46].

Other systems need to be considered, in particular mixed farming systems (plant/animal, agroforestry, intercropping, etc.) with a view to reconsider the role of livestock and forestry in ecological approaches. Developing new farming systems (permaculture, insects, vertical farming, etc.) should also be considered. Research developed in these specific approaches has a potential of spinning out to other systems.

Collaboration with other parts of the food and non-food supply chain are necessary to develop interesting, new and creative solutions especially for radical eco-innovations. The Eco-Innovation Observatory annual reports highlight the benefits from the cooperation of the agricultural primary sector with other sectors like the food and beverage industry, retailers and the water and waste management sector. The role of the consumers is also important to be considered for the adoption and promotion of ecological approaches. The organisation of sustainable food and non-food supply chains is tackled in section 2.4.2.1 on "*new openings for rural growth*". Specifically related to this part, transition pathways will be developed taking account of constraints and lock-ins.

Knowledge on agro-ecosystems is site-specific and evolving. Ecological approaches are knowledge intensive and rest on the integration of formal and practical knowledge with modern technologies. Innovations are expected to capitalise on the specificities of local conditions and provide tailor-made solutions rather than solutions with broad applications. Long-term experiments and demonstrations and adequate research infrastructure need to be developed for the specific needs of ecological approaches regarding the landscape level to be considered and its evolution in a long time-frame (e.g. systems including forestry). Appropriate metrics will be necessary to assess the trade-offs and impacts of various systems at different geographic and time scales on the different environmental issues.

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 tertiary sector appears to be the first job provider and one of the main drivers of economic growth in rural areas, along with the upstream and downstream sectors. New activities have developed, including tourism, small scale and niche manufacturing and food production and business services. ICT

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

development brings solutions to remoteness and opens new business opportunities in a wide variety of fields.

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

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

2.3.2.1. New openings for rural growth

Rural areas supply food, timber, water and a range of ecosystem services and public goods. Yet society's demand for products and services based on natural resources is widening and the capacity of rural areas to match it will contribute to shape their future economic growth. Building on a solid analysis of **territorial dynamics**, research and innovation activities under this priority will contribute to identify new avenues for rural growth in relation to **1) food and non-food value chains**, **2) delivery and economics of public goods**, **3) key other economic sectors** such as services, infrastructures, logistics and digital activities which enable or facilitate innovation and socio-economic 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 **policy-makers,** 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 in the priority. Economic policies supporting growth in rural areas reflect to some extent the underpinning theoretical models prevailing at the time they are implemented. Thus, along the decades, explanatory frameworks have switched from exogenous – i.e. development underpinned primarily by external factors – to endogenous growth – i.e. fostered by own endowment of resources. Current thinking acknowledges the contribution of mixed approaches which aim at mobilising own rural capital (natural, human and social) without neglecting potential support and synergies originating from outside the rural areas. In addition, policies focusing on specific sectors have given place to integrated approaches at territorial level which take account of local circumstances (so-called place-based approaches). On the other hand, policies designed to cope with overarching objectives (such as climate change, biodiversity, trade) have direct and indirect impacts on the primary sector.

In order to properly comprehend the dynamics of development in rural territories, research activities should capture major trends affecting rural areas economically and socially, differentiating 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 market power and concentration in upstream and downstream sectors), changing structures and employment patterns in farming, **climate change**, trends in **services or digital development and their impact on attractiveness**. Research will also capture the **social underpinning** of rural development (e.g. role of networks, citizen's engagement in local decisions and policies, etc.). **Scenario** types of projects and **foresight activities** will be useful to characterise the impact of these trends on rural areas and policies. Further integration of models and data can also support a better assessment of the impact of policies on rural areas (*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 in concerned territories[47]. Some stakeholders argued against putting too much effort on delineating boundaries between different types of territories as these are permanently changing[48]. Various dimensions of linkages between territories can however be investigated, for instance to clarify the analytical framework, to analyse governance approaches which enhance synergies between rural and urban development and between economic sectors in concerned territories and to identify avenues for new business developments building on these linkages will be identified, including social innovation and regional branding. Beyond those linkages, holistic analytical frameworks can be developed, together 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 relations between urban areas and their immediate periphery[49].

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 regarding various quality attributes (authenticity, standards, certification, origin, healthy, local or regional supply, etc.). This can generate higher income to producers, in Europe as well as developing countries (in particular small-scale farmers) and take place at affordable consumer prices on the basis of renovated business models. It is necessary to understand the dynamics of the food chains (and of their components) and the interactions between them and with non-food chains to foster their competitiveness, sustainability and resilience. All dimensions of sustainability will be investigated: **environmental** (resource management, waste reduction at various levels, climate change mitigation and adaptation, biodiversity

[47] Rural-urban partnerships, OECD Rural policy reviews, 2013

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

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

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 inasmuch as they may provide solutions towards improving sustainability and providing territorial coherence and benefits. Cooperative and other collective approaches deliver multiple benefits (increased market power, logistics, etc.). The **role of consumers** needs to be researched as it has a strong bearing on the whole food system and the manner 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. **Drivers of sustainable consumption** need to be better understood (for example when it comes to promoting "integrated ecological approaches" as mentioned in section 2.4.1.3).

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

Finally, **policies shaping food value chains will be analysed**, exploring how intervention modalities can impact environmental, economic and social sustainability as described above.

Agriculture and forestry have since immemorial times produced for other purposes than food, 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 permitted by scientific and technological progress and related promising markets.

Research 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 system-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 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 and by the uses 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 on resource management. 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 socio-economic 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 at a larger geographic scale. Research will extend to the tools,

indicators and forward-looking activities which are necessary for all concerned players 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 environment, culture and heritage of rural territories can be a driver of their sustainable growth. This materialises already to a certain extent for public goods related to culture and heritage for instance through tourism resting on traditional landscapes or traditional food products. However, the situation is less favourable regarding most **environmental public goods** such as water, 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. Agriculture and forestry 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 territories and the benefit from these public goods to the whole society. Research will address the main environmental public goods individually to dig into 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 socio-economic dimensions**, including the coherence for development and the implementation of new policy instruments and delivery mechanisms as well as necessary decision-making and monitoring tools. This will include for example progressing towards **valuation and pricing of public goods**[50] 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 public good delivery will be analysed as well as possibilities to develop collective approaches to public goods provision.

Taking advantage of the digital revolution

Information and communication technologies (ICT) can bring a solution to remoteness and therefore bring new opportunities to develop businesses that could not be established in the past and are likely to raise rural attractiveness 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, to setup innovative marketing channels, such as new modalities of short food supply chains, or to improve logistics. They bring innovative solutions which can help to modernise the provision of services and make it efficient for both providers and citizens in a context of lower population density. ICT can also support a greater involvement of rural dwellers in policy making, networking and collective initiatives enabling a modernisation of governance. Research and innovation activities across the whole priority will explore and upscale business and governance models which can boost rural economies thanks to digital applications.

[50] 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 necessity to foster innovation in agriculture is a message almost universally conveyed 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. Beyond agriculture, innovation in rural areas can play an important role in stimulating a green and socially inclusive economic growth, mitigating geographic isolation and avoiding economic and social marginalisation. Human capital (i.e. individual skills which enable actors to perform or initiate economic activities) and social capital, i.e. links, incentives, shared values and norms which 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 strategy 'Europe 2020'. Horizon 2020 has been consequently aligned towards the objective of fostering innovation. European Innovation Partnerships (EIP) 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[51].

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. Hence, the so-called linear approach, whereby solutions developed by knowledge centres were transferred and implemented uniformly by farmers via the support of advisory services and relevant policies, is no longer sufficient[52]. Dealing with complexity indeed implies to mobilise all available knowledge sources, including tacit knowledge at farm and business level and requires the involvement of all relevant actors (farmers, 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 at supporting sustainable growth in rural areas by fostering innovation. They will have two main dimensions. The first one 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 above-mentioned complex environment. The second one will pay attention to the **knowledge and innovation systems** and aim at improving their delivery.

The dynamics of economic activities in rural areas is heavily dependent on their **social and human capital**. Enhancing innovation implies on the one hand to understand the values that can foster or constrain social capital (such as attitude 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 they need today and in the future. This allows, on the

[51] COM(2012) 79 final

[52] 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).

other hand 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 foster knowledge and innovation in rural areas. This goes well beyond initial education and training as skills need more and more to be maintained all along working lives to keep pace with societal changes.

Horizon 2020 and its succeeding Framework Programme will be mobilised to provide knowledge on the functioning of the **knowledge and innovation systems** with the objective to improve their delivery in rural areas, including recent approaches such as the EIP-AGRI. This will cover all segments of the systems (science, education and training, advisory services), categories of actors (knowledge users, intermediaries and researchers, networks, clusters), types of innovation (technological, social, organizational, etc.) and policies (CAP, research and innovation and education policies). Investigations will cover a large variety of aspects such as: integration of new demands and technologies; impact of participatory research; skills and rewarding of participatory research and more broadly evaluation of researchers; etc. Attention will not be limited to innovation at the farm 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 capacity of policy makers to properly deal with innovation will also be investigated with the aim of facilitating innovation. Benchmarking and exchange of experience between national and regional level knowledge and innovation systems inside the EU will be encouraged. Beyond European borders, the capacity of knowledge and innovation systems to facilitate convergence between agricultural research and practice to better respond to global challenges should be properly looked at.

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 stakeholder consultations foreseen throughout the process.

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

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

3.2. Fostering 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[53]. Building the **European Research Area** (ERA) is a key objective of Horizon 2020[54]. To achieve that, fostering synergies between Member States and between Member States and the EU Framework Programme is a necessity for impact and efficiency. ERANETs, Joint Programming Initiatives (JPIs), Article 185 initiatives can contribute to coordination and integration of research among Member States and the Framework Programme to different extents. Other instruments may also be mobilised to respond to these objectives, for instance European Joint Programmes (EJPs). Synergies will be developed with relevant Joint Programming Initiatives (JPIs) such as FACCE (agriculture, food security and climate change) with a view to enhance the European integration of their programmes.

The objective of fostering coordination and synergies of research needs to be carefully balanced with the objective to involve 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 whereas they have a research capacity that could bring value to these activities.

[53] 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 one should not forget that the nature of what is compared is not exactly the same: EU investments are project investments whereas Member States data cover also running costs of their research and innovation activities. In addition, the multinational nature of Horizon 2020 activities represents often an added value to activities implemented at the national level. Finally, if one would take 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.

[54] COM(2012) 392 final

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[55] 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 through the Common Strategic Framework Thematic Objective 1. 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 the whole world (with automatic funding for developing countries).

On the one hand, international cooperation has a role to play in fostering the **competitiveness** of European economy and the capacity of European research and innovation system itself. On the other hand, international cooperation can make a strong contribution to support the EU's external policy dimension and ensure 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 global level. Demographic, dietary and income trends, climate change and environmental sustainability as well as domestic policies on trade and food distribution are perceived as the major drivers that shape current and future food security. Most of these concerns have an obvious **global dimension**. Therefore, in line with the strategy for **international cooperation** in research and innovation[56] international activities are an integral part of the present strategy. This entails that the EU strengthens its dialogue and cooperation with key international player countries[57] and regions (e.g. Africa, China, the Mediterranean region) as well as with international organisations[58], the private sector and global initiatives to build critical mass and develop synergies to tackle global challenges. The recently adopted Sustainable Development Goals (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** (ARD) will aim at achieving EU wider objectives regarding development and will aim at complementing

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

[56] COM(2012) 497 final

[57] 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.

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

and establishing synergies with other investments made by the EU in this area, taking into account lessons learned from past 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 the approach of DEVCO related to agricultural research for development[59].

At multilateral level, activities will be sought in key areas contributing to support sustainable agriculture and food security, for instance animal and crop health, sustainable and ecological intensification, genetic resources or sustainable forest management. Fostering resilience and dealing with climate change will also be given due consideration. Supporting flexible platforms such as the one that is proposed to be established on animal health in Horizon 2020 work programme 2016/2017[60] will contribute to implement international cooperation. Complementarity and synergies will be sought with the activities of the CGIAR and international initiatives such as the Belmont Forum[61] and Future Earth[62].

To a certain extent, ERA instruments such as ERA-NETs, JPIs, EJPs, Art 185 initiatives, are open to international cooperation. Additional tools, for international coordination include International Research Consortia, 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 essentially in the human health domain. Such IRCs or other appropriate forms of structured international collaboration will be considered in relevant sectors related to agriculture.

3.4. Fostering 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 both in the CAP (at local and regional level) and Horizon 2020 (at transnational level). Operational Groups are the cornerstone of the EIP-AGRI in 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 at establishing a genuine process of co-creation and implementation of knowledge in agricultural and forestry practice. An important part of topics under work programmes 2014/2015 and 2016/2017 involve the MAA and this approach will be continued (with adjustments as necessary) in the coming years.

On the other hand, **knowledge exchange** should be facilitated by supporting transnational networks: thematic networks which investigate particular sectors or issues and networks of experimental and demonstration farms. These networks strengthen connections between concerned actors and facilitate the inventory and use of knowledge as well as the collection of tacit knowledge. They provide inspiration to the actors,

[59] "Research and innovation – Food and nutrition security / sustainable agriculture", DEVCO (2014), available at: https://ec.europa.eu/europeaid/sites/devco/files/guide-approach-paper-ar4d-2014_en_0.pdf.

[60] See topic SFS-12-2016 "Support for international research on animal health"

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

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

stimulate peer-to-peer exchanges and strengthen long-term connections and mutual trust between rural actors.

Implementation of knowledge and solutions on the ground is highly conditional upon the **feasibility 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 is provided. A possible route could be to explore whether a similar 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[63] so as to support ground-breaking solutions.

3.6. Developing synergies with private sector research

Involvement of the private sector will be sought so as to raise the leverage of Horizon 2020 investments and to foster the development of new technologies contributing to meeting the objectives of sustainable primary production. 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 with the EIP-AGRI. Moreover, the private sector devotes most of its research and innovation effort in areas where the return for investment is in the short and medium term. However, enterprises may need specific form of collaborations with public research on long-term research areas of their interest especially when they do not have the in-house expertise or knowledge.

Creativity from small players would need to be incentivised actively. 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 of which SMEs represent the vast majority. Different instruments will be explored in addition to the SME instrument of Horizon 2020. In particular, the role of Financial Instruments, to provide support to start-ups or SMEs in developing new technologies and approaches (e.g. biocontrol industry, ICT in agriculture, animal health, etc.) needs to be investigated.

[63] Technology Readiness Level. TRLs are based on a scale from 1 to 9 with 9 being the most mature technology.