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SYNTHESIS PAPER

THE FUTURE OF SUSTAINABLE AGRICULTURE

WHERE CAN EUROPEAN RESEARCH & INNOVATION TAKE IT NEXT?

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EXECUTIVE SUMMARY

In the global health crisis of 2020, the sufficient supply of safe and locally accessible food grew to be a central concern of citizens and governments. The complex situation reveals our food system's strengths and weaknesses, highlighting the apparent environmental and economic imbalances. By focusing on the most pressing issues for developing a sustainable food system, the EU research programmes in Horizon Europe (and domestic research priorities) can take our current agricultural knowledge to the next stage and create greater food system resilience and deliver on the ambition of the European Green Deal, Horizon Europe.

Resulting from a stakeholder process with environmental NGOs, academia and industry, IEEP commissioned a series of experts to assess relevant topics that will advance a sustainable agricultural transition, with a focus on prioritising research under Horizon Europe. The selection of areas is not exhaustive, but the four research topics were consciously chosen based on the priorities of the involved experts and stakeholders. Soils (Mäder & Bünemann, FiBL); Protein transition (Hubert, Aubert & Loveluck, IDDRI); Short food supply chains (Chiffoleau & Dourian, INRAE); Sustainable crop protection (Nadeu, RISE Foundation).

Soils

Key research focus to date: Recent years show an observed shift in research focus from soil productivity to soil multifunctionality. Relevant EU projects previously researched nutrient management, climate change resilience, biodiversity, carbon sequestration, sustainable management and soil threats.

Research gaps and needs: These include bringing together the previous research and understanding complex factors of soil quality and functions, expanding Agricultural Knowledge and Innovation Systems and advancing carbon farming and nutrient loss reduction techniques. A strong need is to find effective ways to preserve soil biodiversity and promote the application of promising sustainable management practices.

Protein transition

Key research focus to date: There remains an emphasis on dietary shift/consumer level in this research area, and on innovations in the supply chain (aiming to create protein-rich foods) rather than proposing a food system approach. Central themes include resource efficiency (feed conversion, manure management), and the potential of mixed farming in nitrogen recycling, increasing protein supply in the EU and substituting imported proteins.

Research gaps and needs: Evidence-based evaluations of health and nutritional benefits of low animal protein diets, as well as effectively integrating legume crops in farming systems and value chains to improve the varietal selection of pulse and legume crops is key. Different transition pathways lead to diverse needs: Plant-based consumer focus sees needs in input optimisation; following a technological path of low disruption means gaps in low-energy technology innovation research and novel protein sources; achieving extensive, low-chemical input farming system, research needs focus on value chain enhancement of whole sources of protein and job creation.

Short food supply chains

Key research focus to date: Studies analyse the physical distance between producer and end-consumer, the number of intermediaries and more recently the use of digital selling and marketing tools for resilient local food economies. Economically, research revealed an income increase for a great number of farmers in short supply chains, collectives and organic farming

Research gaps and needs: Putting effort in the under-researched area of health and nutrition aspects of SFSCs and their influence on food habits of consumers is key. Data on job creation and quality are gaps, as well as the role in food system transition and their contribution to food system resilience. For better research communication, creating knowledge sharing platforms and training tool can enhance the uptake and upscaling purposes.

Sustainable crop protection

Key research focus to date: These range from Integrated Pest Management to plant resilience, with an increasing shift to placing crop protection in the wider context of agricultural systems. A lack of data saw research focussed on developing assessment tools to work with indicators and management practices.

Research gaps and needs: Plant resilience and diversity goals induce needs in developing good quality monitoring tools for pests and pesticides, boosting natural crop protection through landscape planning and biocontrol, reducing pest resistance and increasing plant and system resilience. Research towards these needs aim for plants to better withstand pressures of pest, diseases and climate change while reducing the negative environmental impacts of synthetic pesticides.

The research needs identified for the four research topic areas demonstrate how Horizon Europe could leverage investment for innovative ways to implement, optimise systems and increase research efforts in agriculture to deliver more sustainable food systems. In the framework of the EU's climate and environmental strategies and in preparation for the EU recovery plan, public funding for research & innovation should be a priority for the EU as well as securing joint funding support through public and private partnerships to leverage private investments that deliver public goods.

- The research gaps point to the lack of **understanding of systemic/holistic approaches** to improving agriculture and food systems which should be a focus on Horizon Europe, including co-benefits.
- Systemic change will bring impact to a greater range of stakeholders, who should be involved in **all stages of the research cycle**, including consumers and citizens in general.
- **R&I budgets should enable the deployment, trialling and upscaling of known techniques and processes** to address current challenges, whilst also focussing on new research areas.
- **Coordinated action** on bringing together Horizon Europe priorities and actions with those of Member States R&I activities, and those of private interests could increase the R&I potential in Europe and deliver greater and more rapid change.
- The choice of agri-food transition pathways will necessitate specific R&I. It is therefore essential that there is a **close and timely relationship** between defining the research needs in Europe with the political choices made around associated policies, such as the Common Agricultural Policy.

1. INTRODUCTION

In the global health crisis of 2020, the sufficient supply of safe and locally accessible food grew to be a central concern of citizens and governments. The complex situation reveals our food system's strengths and weaknesses, elevating the apparent environmental and economic imbalances.

With the **European Green Deal**, the European Commission indicates a clear policy direction for the coming years for an economic and social transition to tackle these challenges. Together with the Farm-to-Fork (F2F), Biodiversity, and Zero Pollution strategy (2021), the Green Deal can establish drivers for change. Next to these strategies, public and private **Research and Innovation (R&I)** programmes enable continuous efforts for innovation. **Horizon Europe**, the EU's framework programme for research, will guide R&I investments from 2021-2027, taking over from its predecessor Horizon 2020. Through focusing on the most pressing issues for developing a sustainable food system, the EU research programmes can take our current agricultural knowledge to the next stage and create greater resilience in our food system.

The premise of this research brief is to give an overview of the **state of play and to explore the main research needs** for sustainable agriculture. The first section captures the state of play with current research trends and achievements of EU agriculture research projects. Future research needs are set out in the following section. The report concludes with the resulting research gaps and strategic priorities, where Horizon Europe should play a role in driving change.

Resulting from a stakeholder process with environmental NGOs, academia and industry, IEEP commissioned a series of experts to assess relevant topics that will advance a sustainable agricultural transition, with a focus on Horizon Europe. This brief is based on the experts' analysis of these issues (detailed papers available separately). The selection of areas is not meant to be exhaustive as it does not include detailed accounts of, for instance, research into water usage, energy consumption/production in farming and the social aspect of a green transition in farming.

The **four research topics** were consciously chosen based on the priorities of the involved experts and stakeholders:

- Soils (Mäder & Bünemann, FiBL)
- Protein transition (Hubert, Aubert & Loveluck, IDDRI)
- Short food supply chains (Chiffoleau & Dourian, INRAE)
- Sustainable crop protection (Nadeu, RISE Foundation)

2. A STATE OF PLAY OF CURRENT RESEARCH EFFORTS

Research and the implementation of innovations are vital to creating sustainable food and agriculture systems. This section summarises the key areas considered in this brief, looking at the current state of EU research programmes and R&I investments

Box 1 - The importance of soil, protein, food supply chains and crop protection research to the future of sustainable agriculture

Soil

The functions of soil are diverse and of great importance to agricultural production. Soils provide the substrate from which plants produce biomass for food, feed, fibre and energy, they conserve biodiversity, regulate the climate through carbon sequestration, and control pests and diseases. Healthy soils are less prone to erosion, and they filter our drinking water. European soils are under threat, experiencing great pressure on biodiversity and soil organic matter.

Sustainable crop protection

Crop protection reduces losses from pests and diseases, therefore lowering costs and increasing net margins. Most forms of crop protection use chemicals which induce negative effects on human health, soils, water and biodiversity. Without crop protection tools (of all types), up to 75% of crops on average could be lost worldwide (Oerke, 2006). Sustainable crop protection should lower risks and the use of chemicals, as regulated in the EU Sustainable Use Directive.

Protein transition

Overconsumption and protein production (notably animal protein) lead to greater land use for feed production and subsequent biodiversity loss and pollution of water bodies. The input of nitrogen through synthetic fertiliser and import of soy drive the environmental imbalance. Plant-based products are becoming prominent alternatives to animal protein: on average 82% of EU citizens would opt for 'less but better meat', 52% would consider replacing meat (survey carried out for the European Commission, reported in (Aiking and Boer, 2018)).

Short food supply chains

Consumer expectations and concerns over food providence raise the interest in short food supply chains (SFSCs) due to a growing interest in quality, local and sustainable food with transparent origin (Goodman, 2004; Kneafsey et al, 2013; Renting, Marsden and Banks, 2003). Short supply chains reduce the intermediaries, focus on the personal interaction between producer and consumer, and foster cooperation between farmers (Chiffoleau, 2009; Marsden, Banks and Bristow, 2000; Renting, Marsden and Banks, 2003). The repetitive health and sanitary crisis at the beginning of the 20th century led to greater interest and research, and today's struggles draw great attention to the topic.

For each selected research field the commissioned experts observed the current **research developments** taking place in Europe. Soil research experiences a shift from the emphasis on productivity towards soil multifunctionality as a central concept, embracing the variety of roles that soil plays in agriculture. On the other hand, the protein transition research area lacks a wind of change since it remains consumer-centric and based on dietary shift – rather than a suggested, better-equipped food system perspective (Aiking, de Boer and Vereijken, 2006; Manners et al, 2020). In the policy domain, animal welfare is particularly gaining importance. Funding is concentrated on down-stream innovation (protein ingredients), with less R&I resources streaming into upstream/midstream innovation related to lock-ins of supply chains for already existing plant protein sources.[1]

The range of Horizon 2020 research projects for sustainable pest control to be broad, from designing cropping systems for Integrated Pest Management (IPM)[2] to building plant resilience (Nadeu, 2020). In the last years, projects have shifted to placing crop protection in the wider context of agricultural systems. In the field of SFSCs, research remains limited (Chiffoleau and Dourian, 2020). Most studies focus on the physical distance between producer and end-consumer and the number of intermediaries. The research trend[3] goes to exploring the use of digital communication and social media as selling and marketing tool, as well as using platforms to build resilient local food economies (Bouré, 2017; Drejerska, Gołębiewski and Fiore, 2019).

Often R&I is presented as the pathway to new creations. However, public R&I funding has great potential to push knowledge to the implementation stage, for instance through the application of **sustainable management practices**. In soil research, the EU projects iSQAPER, CIRCASA, SoilCare and LANDMARK observed a positive impact on several soil functions when using sustainable tools, such as crop rotation, to achieve greater climate change resilience.[4] Nevertheless, the implementation of measures for greater soil carbon uptake is described as slow and measuring long-term soil organic carbon development should be improved (Mäder and Bünemann, 2020).

Correspondingly, in research for the management of pesticide reduction, the DESSA project assessed how farmers with access to real-time support via software connected to sensors in the field could reduce the use of agrochemicals by up to 30% (European Commission, 2020a). The real-time information can inform the correct timing and quantity of pesticides, without reducing crop quality and yield (European Commission, 2020b). In many cases**, tools to improve management** (interactive tools, apps etc.) require further development after project finalisation, although this step is often not recognised as innovation (Mäder and Bünemann, 2020). In the protein transition debate, reducing the environmental impact of protein supply is considered for livestock and cropping systems. For the former, resource efficiency is a central theme (feed conversion, animal diets, manure management) (Westhoek et al, 2011). Research into mixed farming systems demonstrates significant advantages to enable the recycling of nitrogen through manure management (Russelle, Entz and Franzluebbers, 2007).

[1] H2020 LEGVALUE and TRUE - legume-based farming systems; LEGATO project - breaking barriers for grain legume cultivation
[2] Crop protection in the EU is organised through Integrated Pest Management (IPM), meaning prevention, monitoring actions before resorting to the use of chemicals. EU data on pesticides use is only publicly available since 2011 but even this data suffers from several shortcomings such as the fact that not all countries report the same
[3] H2020 SKIN and SMARTCHAIN
[4] Resilience projects Biodiversa projects, EcoServe, SoilClim and ongoing Diverfarming and SURE-farm

Effective implementation of tools to increase productivity and food system resilience requires a base of quality **indicators and procurement of data**. For instance, the EU aims for the use of chemical pesticides to be reduced by 50% by 2050. However the extent of IPM implementation is unclear, as tracking the progress of low impact management and EU data availability is lacking overall (Nadeu, 2020). To address this need, the Horizon 2020 project EUCLID28 focused on IPM indicators by developing an assessment tool to assist farmers in the use of IPM. The project compared different combinations of measures of IPM considering efficacy and direct costs but also impact on health and the environment. Moreover, research on consumer information is greatly based on self-reported motivation rather than behaviour, such as willingness to pay, health information and environmental awareness (Bianchi et al, 2018; Hartmann and Siegrist, 2017; Rolland, Markus and Post, 2020).

Horizon 2020 research projects increased the **understanding and tools** to make changes towards sustainable agriculture. Tools against the loss of soil organic matter are central, as 60-70% of EU soils are described as unhealthy, resulting from the agricultural management practices used nowadays (Veerman et al, 2020). Healthy soil is described as being able to provide essential ecosystem services, including wider ecosystem functioning and society's well-being. Identified measures have been afforestation, wetland restoration and carbon sequestration, the latter being the most complicated regarding trade-offs with biodiversity, yields and pesticide use.[5] To advance sustainable pest control, the ENTOMATIC project developed monitoring technologies for farming and recommending specific actions to farmers.

Questions posed for advancing a protein transition included the increase of protein supply in the EU and substituting soybeans as feedstock or working on animal protein alternatives. The latter was highlighted in a recent "Alternative protein for food and feed" programme looking at insects.[6]

More detail on the findings on these four research topics can be found in the dedicated research briefs.

[5] 4 per 1000 initiative, CIRCASA, TILMAN-ORG and Eco-Serve

[6] SUSINCHAIN, NEXTGENPROTEIN) microalgae (PROFUTURE, NEXTGENPROTEI), microbial protein (NEXTGENPROTEIN) and fungi and pulses (SMART PROTEIN).

3. SUSTAINABLE AGRICULTURE AND HORIZON EUROPE – RESEARCH PRIORITIES

This section presents an outline of important needs for key agriculture research areas. To improve food system resilience and nutrition in the times of climate change and a global health crisis, it is not sufficient to rely on traditional methods. Horizon Europe needs to consider a systemic approach to developing resilient farming systems in the long run and programme its research accordingly. Three overall aspects are suggested in this brief: continuing research, optimising practices and innovative implementation.

3.1 Areas requiring ongoing research

All experts point towards the need of intensifying current research efforts in Horizon Europe. In future EU R&I programmes for soil health and quality, the **complex and important linkages** between soil health, plant health and **human health**, following the 'one health' concept, are key research needs (Mäder and Bünemann, 2020). Understanding the connection between the health of soil and human health goes beyond previous projects work on the relationship between solely management, soil and plant health.

Likewise, Hubert, Aubert and Loveluck (2020) suggest evidence-based evaluations of the health and nutritional benefits of low animal protein diets, which can in turn lead to an understanding of effective levers at the consumer level of foods with lower land use and climate impact (Hubert, Aubert and Loveluck, 2020).

Similarly, Chiffoleau and Dourian (2020) suggest focussing on the under-researched area of health and nutrition aspects of SFSCs as well as their influence on food habits of consumers who recently entered them (Chiffoleau and Dourian, 2020). With the global health crisis of 2020, Horizon Europe can and should respond to the increased interest in safe, transparent and local food supply.

Changes in consumption patterns should be analysed on the level of **agri-food chains**, meaning logistics, assets and jobs, as well as food loss and waste (Hubert, Aubert and Loveluck, 2020; Stenmarck et al, 2016). Particularly for the post-COVID recovery, identifying investment needs and job creation opportunities will create a clear picture of the potential for social, economic and environmental delivery.

The connection to SFSCs is interesting as research on the economic side revealed an income increase for a great number of farmers in short supply chains, collectives and organic farming (Capt et al, 2011; Morizot-Braud and Gauche, 2016; RCC, 2013).[7] Moreover, Chiffoleau and Dourian (2020) indicate the research needs around job creation and quality (Chiffoleau and Dourian, 2020). Past national surveys analysed in this context did not take the job quantity created along the entire chain (for instance a strong relation with agritourism) and in territories into account, therefore dismissing the economic impact SFSCs could have.

Keeping the EU Green Deal and the COVID-19 pandemic in mind, priority gaps to fill through Horizon Europe include **understanding of the role** of SFSCs in food system transition and their contribution to food system resilience (ibid). The greater use of SFSCs for sustainability and social benefits and the up-scaling of SFSCs is under researched, and would rely on analysis of suitable technologies, economic and local food policies and more. Short supply chains are furthermore perceived as more resilient to economic and environmental shocks. For a full understanding of their potential impact on food system resilience, research must take

[7] STRENGTH2FOOD

into account actual synergy or competition of short and long, local and global chains and the impact on international trade flows. Creating a conversation about international fair trade and resilience of food systems in both the global South and North can be an effective outcome of this path.

Plant **resilience** debates are rather of social and legal nature, with impacts materialising over the long-term as resilience becomes apparent. As such long-term experiments to increase plant diversity in agricultural systems are necessary (Nadeu, 2020). This would include the development of under researched locally adapted resilient varieties. Sustainable measures and practices that create a resilient and diverse plant base are anticipated to be better able to withstand pressures of pests, diseases and climate change while reducing the negative environmental impacts of synthetic pesticides, but require better R&I to demonstrate these effects and how they can best be delivered.

Diversity of crops and crop production is likewise key for a protein transition, putting an R&I focus on the production and development of different protein land-based (pulses etc.) aquatic (duckweed, algae etc.) and microbial/synthetic sources. The potential impact of a shift on biodiversity is also important. Making full use of a diverse range of pulses with multiple health and environmental benefits has not yet been translated into research funding to address greater uptake in supply chains for legumes. Until now, wheat and rice have more widely benefitted from innovation budgets over pulses (Magrini et al, 2018). Together with an envisioned reduction of protein imports through economics mechanisms, this step requires further research into competition and trade policy.

Table 1 Research needs sustainable crop protection (Nadeu, 2020)

		Research gaps		
		Monitoring pests and pesticide use	Boosting natural crop protection	Reducing pest resistance and increasing plant resilience
Challenges	Reducing impacts	X	X	
	Tracking IPM progress	X		
	Lack of indicators to measure SUD progress	X		
	Adapting to new conditions without increased impacts	X	X	X

Creating **novel monitoring tools and indicators** is central to track progress and adjusting measures to ensure effective impact on the ground. Nowadays, EU indicators largely only consider the pesticide treatment frequency and not the type of pesticide. This system makes it difficult to track the impact of pesticide use and the guiding policies on human health. Indicators that show the change in risk and that make the connection to human health impacts are a necessary way forward for Horizon Europe (Nadeu, 2020).

Similarly, **farming techniques** for soil carbon storage show potential for Horizon Europe projects. Yet, these techniques remain expensive and lack comprehensive data to support their development. Mäder and Bünemann (2020) accordingly identified the need for low-cost methods for measuring soil organic carbon, carbon storage potential in lower soil layers and the development of databases for soil organic stock development modelling (Mäder and Bünemann, 2020). Future studies should consider various management practices and different climate change scenarios, which is not the case for many current programmes.

3.2 Optimising available techniques, technologies and systems

Existing research and methods can benefit from R&I spending through enhancement and optimisation. For instance, Mäder and Bünemann (2020) recommend Horizon Europe to fund research into **optimising cropping systems** which can respond effectively to the objectives set in the recently published F2F strategy and biodiversity strategy (Mäder and Bünemann, 2020). Scaling-up existing sustainable farming systems, practices and approaches would also be possible since tools to assess them on a larger scale are mostly available.

Combining agricultural practices, such as reduced tillage without herbicides and crop diversification, can enhance both soil health and the implementation of IPM (Mäder and Bünemann, 2020; Nadeu, 2020). This need goes back to the conflicting environmental effects of current management practices, where in turn novel systems have the potential to safeguard soil-based ecosystem services. Moreover, biocontrol toolboxes should be able to deal with an expansion of organic agriculture and pesticide reduction targets resulting from the European Green Deal. This would necessitate a focus on identifying those weeds or pests that do not generally require chemical pesticides (Nadeu, 2020).

Likewise, it is of interest to know the effect that SFSCs can have on farming and processing techniques, particularly for newly participating actors (conventional farms, 'average' consumers) (Chiffoleau and Dourian, 2020). In order to know if a short supply chain can reduce farming emissions and create a thriving and connected countryside, there is a need to direct Horizon Europe research towards **optimising logistic organisation and governance** in rural areas and small cities, rather than support only being directed at large cities (as has been the case so far).

The research needs for a European **protein transition** can play out differently according to the pathway of change that is chosen. If the focus is envisioned to shift to sustainable intensification and efficient nutrient application to change protein consumption and its impact on the climate, the research focus would change accordingly.

To achieve a change which encompasses a substantial **consumer shift** towards plant-based products, Horizon Europe projects would need to seek optimised use of synthetic nitrogen and other inputs to achieve high inputs with low environmental and climate impact.

Choosing a rather **technical route**, on the other hand, would lead Horizon Europe researchers down a path of low-energy technology innovation research and novel protein sources, potentially creating the least disruption to consumer habits while lowering GHG emissions.

On the other hand, when aiming at achieving an **extensive, low-chemical input farming system**, research would need to focus on value chain enhancement of whole sources of protein and job creation to balance the lower number of farm jobs in this scenario and the substantial structural changes in the food system. The latter approach aims to recouple crop and livestock production while stepping away from synthetic nitrogen.

The choice of transition pathway will necessitate specific research needs, and thus it is essential that there is a close and timely relationship between defining the research needs in Europe with the political choices being made.

3.3 Innovative ways to make implementation successful

Several of the topics discussed would benefit from research financing being directed at the implementation of past discoveries. Although not recognised as 'innovation' by all, knowing how to effectively implement, for instance, a management system translates the theory into practice.

Soil health and pesticide reduction targets will profit from the implementation of sustainable management practices, particularly the **research related to reducing economic and social barriers**,

therefore improving logistics and channelling investment support. For a sustainable protein transition, greatly integrating legume crops in farming systems and value chains is expected to improve the varietal selection of pulse and legume crops and understand their co-benefits (Hubert, Aubert and Loveluck, 2020).

Another point is to observe the application of organic agricultural methods (mechanical weed control, mixed cropping etc.) in a conventional system in order to observe the impact of such changes outside of certified organic production (Mäder and Bünemann, 2020). Such changes come hand in hand with sustainable crop protection techniques and reduced pesticide input (Mäder and Bünemann, 2020; Nadeu, 2020).

Though a great number of **assessment and monitoring** tools have been developed, they lack research and evidence into more effective ways of implementation and greater uptake in practice. This should be supported through Horizon Europe. Existing tools should be applied in different pedo-climatic and farming conditions to show differences, for instance for soil quality (Mäder and Bünemann, 2020). Monitoring of pesticide residues or other pollutants is more complicated and under-researched due to the EU not requiring agricultural soil to be tested for these (Nadeu, 2020) and should therefore be subject to new research.

Sustainable methods of production are knowledge intensive, but education, public awareness raising and acceptance can promote the implementation of promising agricultural practices for soil health, reduce pesticide use, a protein transition and short food supply chains. Therefore, enhanced **communication of research outcomes** to stakeholders and the wider public are central to creating greater impact. R&I is a key tool to building these bridges and should have special focus in Horizon activities as a horizontal theme. Chiffoleau and Dourian (2020) suggest shifting the research focus on SFSCs to creating experience- and knowledge-sharing platforms as a basis for upscaling[8], as well as implementing training tools to share skills for developing SFSCs (Chiffoleau and Dourian, 2020). Enhancing agriculture knowledge and innovation systems should further bring the vast amount of knowledge from past Horizon projects to the field so that existing and new approaches build on the research work undertake so far. Establishing co-learning practices for farmers, advisors and researchers, sharing collective knowledge and practices is another suggestion (Mäder and Bünemann, 2020).

[8] SMARTCHAIN, SKIN

4. HORIZON EUROPE AND AGRICULTURE – NEXT STEPS

The research needs identified for the diverse research topics demonstrate how Horizon Europe agriculture R&I could leverage investment for innovative ways to implement, optimise systems and increase new research efforts. In the framework of the EU's climate and environmental strategies and in preparation for a recovery plan, public funding for research & innovation should be a priority for the EU as well as securing joint funding support through public and private partnerships to leverage private investments that deliver public goods.

Beyond the specific findings of the four research briefs summarised here, there are emerging themes that could help to guide Horizon Europe in delivering more impactful and relevant agriculture R&I that meets the needs of society.

- Above all, there remains a clear need for **significant R&I efforts within the agri-food system** space in Europe. The European Green Deal signals a social and economic transition which puts significant focus on the way in which land is used and managed. Priorities for the restoration of biodiversity and ecosystems, the greater emphasis for reaching net-zero emissions, alongside the necessity for greater resilience of our food systems raises significant questions about how to move forwards in EU land use, as does the EU's commitment to the UN SDGs. R&I is essential to allow no-regret changes to take place now, whilst systemic change begins.

- The research gaps point to the lack of **understanding of systemic/holistic approaches** to improving agriculture and food systems. Existing research has largely focussed on specific themes of production, or stages within a supply or value chain. The scale and urgency for shifting agricultural activities require more of a systemic shift and thus greater R&I investment into levers for such a shift and the impact of any changes.

- Systemic change will impact a greater range of stakeholders, beyond the traditional focus on agricultural producers/processors. It is important to **involve a wide range of stakeholders at all stages of the research cycle**, including consumers and citizens.

- Improving the EU agri-food system will not always require new or novel approaches. There is much that can be gained from existing and past research, but which has yet to reach the field. **R&I budgets should enable the deployment, trialling and upscaling of known techniques and processes** to address current challenges, whilst also focussing on new research into areas yet unaddressed.

- Horizon Europe represents one aspect of the EU R&I portfolio. Domestic, private and EU level R&I budgets and focus, should be better aligned. This could leverage the collective power and innovation abilities beyond any one approach. A coordinated action on bringing together such innovation streams would add value to Horizon Europe and could increase R&I potential to deliver greater and more rapid change.

- The choice of agri-food transition pathway will necessitate specific R&I. It is therefore essential that there is a **close and timely relationship** between defining the research needs in Europe with the political choices.

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