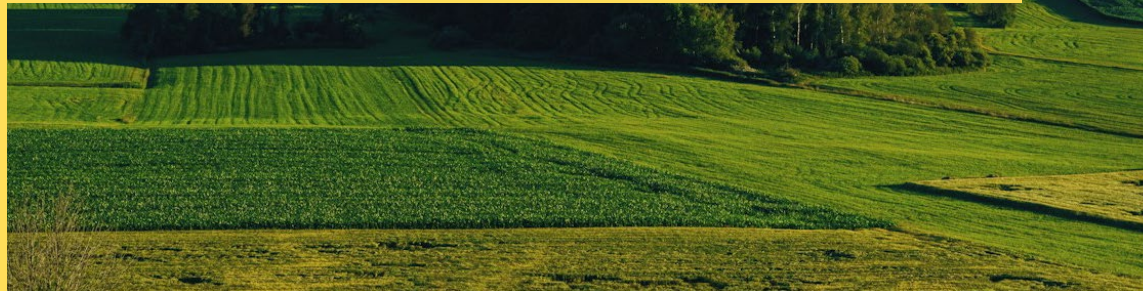


SYNTHESIS PAPER

The future of sustainable agriculture

Current and future R&I priorities



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THE REPORT SHOULD BE CITED AS FOLLOWS

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The European Sustainable Agriculture Dialogue (ESAD) is a multi-stakeholder platform created in 2019 that brings together key actors from across society – including industry, civil society, universities, and research centres – to discuss key topics, exchange our views and standpoints, and ultimately shape decisions towards sustainable agriculture. The brief was developed in consultation with ESAD members and the authors took their inputs into account in the drafting process. The paper does not reflect the views and opinions of single ESAD members. As such, their contribution is not to be interpreted as an endorsement of the final paper.

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EXECUTIVE SUMMARY

This synthesis report aims to gather the outcomes and recommendations from several research briefs prepared within the ESAD platform. ESAD stands for the European Sustainable Agriculture Dialogue, where stakeholders from diverse sectors and interest groups were brought together under the auspices of the IEEP. The purpose is to build a solid argumentation usable at the interface between science and policy for influencing the shape and design of the next EU research and innovation (R&I) programme, known as FP10.

This exercise is particularly important as food security and food safety in the next decades will oblige the food and farming systems to operate deep changes to adapt to the planetary challenges of global warming, biodiversity loss and natural resources exhaustion, while remaining competitive. All the dimensions of sustainability will be seriously challenged and only R&I can bring forward innovative solutions to move ahead.

The results of the exercise performed by ESAD over two years are outlined in this report. Through the research briefs' outcomes and findings, the synthesis report identifies the key priorities towards which research should be directed, as follows:

- Addressing knowledge gaps in agricultural research,
- Rebalancing competitiveness and sustainability in the farming sector,
- Tackling adaptation to global warming and restoration of biodiversity,
- Investing in resilient food systems and demand for sustainable products,
- Committing to open governance in agricultural and food R&I.

Although not claiming to be exhaustive, our method takes advantage of other elements from the literature, and of the ongoing discussions on the future of FP10 to deliver a series of recommendations and conclusive remarks that will be key for making every euro invested in the European R&I a lever for accelerating the transition of agriculture and food systems:

- Agriculture and food R&I needs increased financial resources,
- Partnerships, living labs and novel integrative dissemination tools should be reinforced,
- A holistic vision should govern the design of the programme, leading to concomitant and coordinated changes of all actors involved.
- Competitiveness and sustainability should be simultaneously considered, bearing in mind the contrasted time horizons of their corresponding impacts.

INTRODUCTION – THE EU’S R&I LANDSCAPE

The EU research and innovation (R&I) programmes run for a 7-year period. It is time to turn the ongoing reflections on the future orientations of the next multi-annual programme (the 10th of the so-called “Framework Programmes”, hence FP10) into solid recommendations for the policymakers. Now that the new European Parliament (EP) is elected, and that the new European Commission (EC) is in place and confirmed, the periodical discussions on the multi-annual financial framework (MFF) of the EU is starting. The MFF will allocate the budgetary envelopes that will be attributed to the diverse EU policies from 2028 to 2035. Among those policies is R&I, with the current programme Horizon Europe (the name for FP9) covering the period 2021 to 2027.

The timing of EU programmes, the R&I selection process and the EU decisional regime mean that the first FP10 projects will in practice become operational in 2029 and their first results cannot be expected before 2033. Consequently, our reflection should encompass agricultural R&I needs in the '30s of the 21st century, even though we are still in the middle of Horizon Europe. Only Horizon 2020 (the name for FP8) projects are completed at this time, which findings can be captured and used for concrete investments on the ground and bring impact on the agri-food system.

The European Commission periodically delivers evaluations of its publicly funded programmes. As one can understand from the timeline, no full evaluation of Horizon Europe is available yet, but an interim evaluation of the first years of implementation, representing approximately one-quarter of the overall budget, takes stock of the initial results of Horizon Europe, allowing for some early conclusions. An expert group had been set up and chaired by former science minister of Portugal, Professor Manuel Heitor, and delivered a set of recommendations for enhancing the remaining years of Horizon Europe, as well as feeding into the preparation of FP 10 (European Commission, 2024 a).

Given this global R&I landscape in which agri-food research is embedded, the present paper attempts to identify some of the most prominent challenges and the most critical issues that food and farming systems will face in the next 10 years and beyond, that should be encompassed by the future R&I programmes. It builds on several research briefs produced by the IEEP and partnering research organisations, in the context of the ESAD that will be synthesized in the course of this paper.

Box 1: What is ESAD?

To help shape the future of public agricultural research and innovation in the EU, IEEP has created the European Sustainable Agriculture Dialogue (ESAD), which is a platform bringing together key stakeholders from diverse sectors and interest groups related to EU agriculture and food. In 2023 and 2024, in view of the next European research programme FP10, ESAD's work focused on the research needs to get the EU farm and food system turned into a sustainable system, given the challenges posed by climate change, biodiversity loss and planetary boundaries. To that effect, experts provided science-based inputs and research briefs on a number of key items, which are used by members to inform their debates and are published by the IEEP.*

**The content published in relation to ESAD is produced by independent experts in consultation with group members or in a stakeholder process with the members. Publications do not reflect the views and opinions of single ESAD members involved. As such, their contribution is not to be interpreted as an endorsement of research and policy recommendations.*

Naturally, past and on-going research works on agriculture and food in the context of Horizon 2020 and Horizon Europe as well as the experience gained through these programmes are equally taken in account in this paper (more details on the current process for agricultural research are given at in Annex 1).

We must also emphasize that the scope of this synthesis brief relates to food from agriculture only. It focuses on R&I for the agricultural sector, but not on the fisheries and aquaculture, nor the technologies that would support the development of novel foods like cultured meat or algae-based foods, etc., although they would deserve their spotlight also.

In the final chapter, we deliver conclusive remarks with a view to influencing the agriculture and food R&I agenda in the FP10 to come.

KEY TOPICS FOR FUTURE SUSTAINABLE FOOD AND FARMING SYSTEMS

Objectives already identified by the IEEP and ESAD in the perspective of Horizon Europe (IEEP, 2020 a and b) remain valid for the future, but the issue of adapting to global warming has become even more crucial. Firstly, the contribution of agrifood systems to total EU emissions is still close to one-third (EPRS, 2023) while the EU committed itself to zero emissions by 2050. Secondly, drought, flooding and more and more unstable weather had significant impacts on harvests, yields and farm income in recent years.

Climate adaptation will become the first preoccupation of farmers, as the agricultural sector is highly exposed – and most likely the first and most exposed sector - to rising temperatures, water shortages, biodiversity loss and natural disasters. Farmers will have to adapt quickly and the EU agri-food sector as a whole will face a huge challenge in achieving profound changes at all levels over the next three decades: on-farm, at the processing stage and distribution networks, trade, and consumption patterns in order to get to a genuinely sustainable food system. We examine how the concepts of sustainability and resilience could guide the transformation of food systems in the right direction (ESAD research brief 1 in Box 2).

As stated above, swift adaptation of farming and food systems will represent a huge challenge that only R&I has the capacity to overcome by proposing implementable solutions in the short to medium term. Innovative sustainable solutions can solve the many issues at stake, including maintaining farming activities and farm income. This is why R&I should support the **transformative innovation** concepts, that a research brief examines in depth (ESAD research brief 8 in the table above). They will be key for enabling the farming community to implement the necessary solutions.

ESAD explored specific topics along the food supply chain, starting from the soil. The **soil microbiome** plays a crucial role in healthy functioning soils and ecosystems but also in the health of humans and animals (research brief 2 in the table above). At the farm level, the way to sustainable agriculture passes by combining improvements in productivity together with the delivery of enhanced ecosystem services. **Crop diversification** is recognized as a central strategy to that effect (ESAD research brief 5).

Nitrogen in agri-food systems plays a key role in productivity but has a negative impact on the environment, that must be mitigated (ESAD research brief 6 in Box 2).

Box 2: Research briefs that were produced under the ESAD (2023,2024)

1 – Sgarbi, F., Nadeu, E. 2023. *Resilience and sustainability in food systems research: a review of the main issues and knowledge gaps*. Institute for European Environmental Policy, Brussels.

2 – Nadeu, E., van Dijk, R., Hiller, N. 2023. *The Soil Microbiome: its contribution to soil health and One Health*. Institute for European Environmental Policy, Brussels.

3 – Underwood, E., Tremblay, L., Meganck, K., Moret-Bailly, S. 2024. *Advancing Biodiversity monitoring in agricultural landscapes*. Institute for European Environmental Policy, Brussels.

4 – Antonelli, C. 2024. *Addressing food waste in the retail sector*, Institute for European Environmental Policy, Brussels.

5 – Antier, C. 2024. *Research and Innovation priorities for diversification of cropping systems*. UC Louvain, Ottignies-louvain-La-Neuve.

6 – Einarsson, R. 2024. *A sustainability-oriented research and innovation agenda for nitrogen in the food system*. Swedish University of Agricultural Sciences, Uppsala.

7 – D'Alessandro, C., Menza, G. 2024. *Improving Innovation Uptake and Impact in EU-Africa Collaboration on R&I for Sustainable Food Systems*. European Centre for Development Policy Management, Brussels.

8 – Brunori, G., Muro, M., 2024. *Transformative innovation for the ecological transition of food systems*. University of Pisa, Pisa.

The EU is committed to halting the loss of biodiversity and restoring ecosystems, a commitment that was reinforced with the adoption of the Nature Restoration Law. Agriculture is again the most concerned sector on the matter but to assess progress made there is a need to set measurement methods, metrics and

indicators. For this **biodiversity monitoring**, examined in a research brief (ESAD research brief 3 in Box 2, in situ observations and expertise are paramount, while technologies such as remote sensing, robotics, DNA-based assessment, and others can supplement them.

At the other end of the food chain, next to food losses registered at farming, processing and distribution levels, consumers are responsible for most **food waste**. This issue is tackled in the corresponding research brief (ESAD research brief 4 in Box 2).

Finally, alongside the EU dimension of agricultural R&I, the international dimension focuses on Africa with the research brief on the **EU-Africa collaboration** (ESAD research brief 7 in Box 2).

RESEARCH GAPS

The ESAD research briefs allowed identifying a number of research gaps that hinder the development of resilient, equitable, and sustainable food systems. They span across the food chain however with varying importance depending on topics and the nature of the issues at stake, emerging issues requiring more scientific research to acquire fundamental knowledge. We clustered the gaps into four main categories, illustrated by the following examples:

Knowledge gaps:

In the domain of soils, only a tiny fraction of the microbes has been studied so far: less than 1% of them, when we know that one gram of soil contains more than fifty thousand species of microbes. There is a deep knowledge gap in the description of the soil taxa and, as a consequence, in understanding the role of the microbiome in the multiple soil functions. Another knowledge gap in agronomic research is about the ecology of diversified cropping systems which can contribute to identifying successful farming practices and encourage the uptake of for crop diversification.

Quantification and measurement:

In several research briefs, the question of quantifying flows like nitrogen flows or food waste flows was identified as requiring more research. This applies too to the biodiversity monitoring tools which require more research for the validation of methods of measurement of indicators.

Economics:

Innovative practices for crop diversification need cost/benefit analysis to highlight the most profitable options. At the value chain level, innovative tools are needed for sharing of investment risks and costs during processes of sustainable transition. There is a need to investigate how fiscal measures could help reduce food waste at the consumer level. In international cooperation with Africa, the knowledge on how financing mechanisms and private partnerships can better support innovation uptake is too limited.

Governance:

More research is needed for adopting a systemic approach that tackles all stages of food systems, being for reinforcing their resilience or reducing food waste. This is valid also for transformative innovation, where on addition more inclusive research methods that engage stakeholders in co-designing solutions are needed.

Beyond the illustrations given above and taking a more general viewpoint, several research gaps persist when aiming at sustainable food systems despite the significant progress registered in past R&I programming periods. They are more frequent through the off-farm part of the food chain, in particular about consumer behaviour. We still need to explore how to encourage the adoption of sustainable diets and foster demand-driven sustainable food. Emerging and rapidly evolving issues like digitalisation, the internet of things, robotics and AI do require more research to assess the relevance and risks of these technologies at all stages of the food systems. Another crucial domain is acquiring scientific knowledge about circularity and how to optimize the efficient use of natural resources like land, water, energy, etc.

Addressing these research gaps will require coordinated efforts across the EU, uniting national authorities and regions, universities and research centres, farmers and cooperatives, the food industry and civil society. We need a systemic approach and interdisciplinarity as appropriate, intending to fill these gaps with the help of FP 10. It is essential for building resilient and sustainable food systems that can meet the challenges of the future.

PRIORITIES FOR FP10

Based on the mapping of research gaps, each ESAD research brief went on to set research priorities for the future FP 10 programme. The full list can be found in Annex 2 of this paper. Here we develop a list of priorities for food and agricultural research, also taking into consideration other elements published by the Commission about “Food 2030” (EC, 2023) and the recommendations by the high-level expert group for FP10 in their so-called Heitor report (European Commission, 2024 a). We selected five key items that should be retained in the shaping of FP10 when it comes to R&I for agricultural and food systems.

1) Addressing knowledge gaps in agricultural research

With ESAD we showed through the examples of the soil microbiome and crop diversification that significant knowledge gaps limit the sector's ability to respond to emerging challenges effectively. FP10 should embark on a strategy to address research gaps and develop a deep understanding of biological mechanisms and functional ecosystem services. Collaborative research, partnerships and missions should **continue expanding knowledge** in key areas like soil health, efficient water usage, relevant plant breeding methods, animal health and animal welfare and socioeconomic implications of agricultural innovations.

2) Rebalancing competitiveness and sustainability in the farming sector

ESAD research briefs (e.g. crop diversification, transformative innovation) shine a light on **conciliating productive capacity with sustainability and resilience**. The food and farming sector will be facing the dual challenge of remaining competitive in increasingly globalized markets while addressing enhanced environmental and social concerns. FP10 should support R&I which will help strike the right balance between competitiveness and ecological integrity in the systemic transformation of the EU farm and food systems.

3) Tackling adaptation to global warming and restoration of biodiversity

Among the societal challenges that are currently not sufficiently addressed as highlighted in recommendation 7 of the Heitor report (*European Commission, 2024 a*), climate change and biodiversity loss constitute an immediate threat to agriculture and eventually to food security. In FP 10 the two items should get priority over other issues to make resilience the guiding principle in transforming agri-food systems, using **a mix of technological solutions and agro-ecological approaches** or nature-based solutions, along with the recommendations of the ESAD research brief (ESAD research brief 1 in Box 2).

4) Investing in resilient food systems and demand for sustainable products

Past and ongoing projects in agriculture and food R&I tend to focus on the production side of the food supply chain. More attention should be paid, in FP10, to the consumption side of the food chain. We already saw in the ESAD research brief (research brief 4 in Box 2), how food waste poses a serious challenge to the efforts in making food systems more sustainable. Research should open **new avenues for food policy** thanks to a more holistic and strengthened science–policy–society interface. It should address the big challenge of transforming food systems - one of the most challenging transitions – that needs a renewed conceptual thinking for R&I and a clear directionality so as to achieve a system change that meets the societal challenges of resilience and sustainability.

5) Commit to an open governance in agricultural and food R&I

Horizon Europe registered some progress in the governance of the research programme, like the application of the concept of co-creation, that should be pursued with FP10. Mission and partnerships were novelties that deserve to be maintained and further streamlined in FP10, which would open the question of defining new Missions in FP10. Strong candidates in relation to food could be pesticide-free farming, plant-based diets, zero food waste and certainly others to be further discussed. Several research briefs from the ESAD promote **enhancing stakeholder engagement** in research processes so as to align innovation goals with societal values and long-term ecological goals, like the SDGs. There is also the need to adopt systemic approaches, hence countering the tendency to work in silos. This principle would apply from top to bottom i.e. starting from the European Commission where all DGs should gain coherence by coordinating their policy objectives down to the local level where all actors should work together, inspired by the functional model of the EIP-AGRI.

CONCLUSIONS

The ESAD initiative has opened up a rich and constructive dialogue on the subject of agricultural and food systems, focusing on the R&I needs for the future. Even if we assumed in this exercise that the EU would devote a budget to FP10 at least equal to that of the previous research programme, Horizon Europe, we must underline in this conclusion that the allocation of funding to agriculture and food remains a subject of preoccupation. A key message to policymakers is that **agriculture and food R&I needs increased financial resources** to deliver on sustainable transition and eventually guarantee food security and safety in Europe and to contribute to food security and safety in the rest of the world, in particular in Africa. Another implicit assumption was that knowledge transfers, the uptake of research findings, the deployment of sustainable innovative solutions would continue to make progress across the community of farmers and across the food industry companies. Progress has been registered under Horizon Europe thanks to the EIP-AGRI and other ways of dissemination well adapted to the agricultural sector such as the living labs or the lighthouse factories in the case of food processing. Hence another key message is that **partnerships, living labs and novel integrative dissemination tools should be reinforced** under FP10 to accelerate the transition.

Analysing the ESAD research briefs and attempting to draw a synthesis of the outcomes and priorities, led to a series of conclusive remarks for the future R&I programme, which are listed in the chapter above. For maximizing the leverage effect of EU public support in agriculture and food R&I in FP10 it will be essential that **a holistic vision will govern the design of the programme**. This characteristic is fundamental because research will have to address the complexity of situations and problems for leading to the transformative solutions that will enable genuine system changes, i.e. **concomitant and coordinated changes of all actors involved**. We should highlight the absolute need to encompass the dual role of food and farming systems, on the one hand, the ability to produce food and biomass and, on the other, responsibility for managing and maintaining the land as well as regenerating the natural potential of soil, water and natural resources; **competitiveness and sustainability should go hand in hand** in that respect.

Finally, the varied composition of the ESAD group and its working method, founded on mutual respect and open dialogue through discussions and comments on the draft research briefs has made it possible to elaborate a number of key messages that will help inform the future R&I programme of the EU. Certain domains, however were left outside the scope of ESAD, like novel foods or aquaculture, and would deserve further study with a view to give a more complete picture.

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Annex 1 Past and ongoing research works on agriculture and food

As of 2014, agricultural research was singled out in the EU's research policy so as to better respond to farmers' needs and accelerate research findings dissemination among the farming communities. To that effect, a specific portion of the research budget is managed by the DG in charge of agriculture and rural development within the European Commission, DG AGRI. Dedicated units across the European Commission support the work by designing the Work Programmes and the topics, while the execution of the agricultural research programme i.e. launching the calls, ensuring a fair selection of projects, their follow-up and reporting correct, as well as the corresponding payments from the EU budget, is outsourced to the executive agency REA (https://rea.ec.europa.eu/index_en). Back then, the budget was about 1 bn Euro. This amount tripled for the following programming period 2020-2027 with the adoption of Horizon Europe, agriculture research benefitting from a ring-fenced budget for DG AGRI under the "Cluster 6" of Horizon Europe.

With this generous budget allocation, EU agricultural research is doing well: many projects and partnerships have been set up, covering the whole spectrum of on-farm issues worth investing in more research. Furthermore, DG AGRI developed its own dissemination tool with the European Innovation Partnership EIP-AGRI (<https://ec.europa.eu/eip/agriculture/en/>) aiming at bringing research findings to the fields and offering a space for researchers and farmers to meet, exchange and impulse innovative sustainable solutions.

Against this background and looking forward at the FP 10, the question of budget and the adequation of its size to the actual needs remains valid. This comes from the fact that publicly funded agricultural research remains the principal source of innovations for farmers (IEEP, 2020 b), within Europe and beyond in the developing world. In this latter case, farmers and the food industry may also rely on R&I spillovers, generally subject to the adaptation of knowledge and technology to local economic and agroecological conditions. This places more responsibility on rich countries, the only ones able to increase their R&I intensity, among them notably the EU.

Another feature in this landscape is the tendency to work in silos. Although some progress has been made in Horizon Europe, as the European Commission opted for co-creation of the Work Programmes, approaches are still guided by research needs expressed by narrow sectors. There are separate R&I agendas for agriculture with DG AGRI, for bio-economy with DG RTD, for fisheries with DG MARE, etc, and a subsequent lack of cross-information within the researchers community.

Annex 2 Selected research priorities from ESAD research briefs

1 - Sustainability in F&F systems

- Definition of concepts
- Identification of potential shocks and stress affecting food systems. Metrics and indicators to measure resilience: robustness assessment standards, adaptability capacity (mid-term) , transformability enabling (long-term)
- Stakeholders involvement (perception of resilience as a vector to sustainability) notably farmers
- Actions for enhancing food systems resilience: technological solutions, agroecological approaches
- Governance, connection to global networks as well as regional initiatives

2 – Soil microbiome

- Characterisation of the soil microbiome and development of standardized metrics
- Improved capacity to map, model and predict the soil microbiome,
- Research into farming practices that can enhance the soil microbiome and its benefits (plant diversity, organic fertilisers, biocontrol)
- Elucidating the role of the soil microbiome in the One Health approach

3 – Biodiversity monitoring

- Technologies are available but some need improvements and validation of reliability before committing to monitoring programmes
- Technologies supplement rather than replace in situ observations and taxonomic expertise.
- Automatic recognition systems need training and verification against datasets – and expert taxonomy checks and auditing – to avoid locking in taxonomic errors
- Equality of access issues: governments, agencies, and individuals vary greatly in their ability to access and pay. For the public sector, there is the challenge of paying the costs on a long-term basis.

4 – Food waste

- Prioritize Sustainable Development Goals (SDG 12.3) and EU Green Deal Goals. Future political milestones should focus on aligning with SDG 12.3, the EU Green Deal, and the Farm to Fork Strategy to drive measurable reductions in food waste. Political commitment and targeted actions are needed at both EU and Member State levels.
- Increase Funding for Technology and Public-Private Partnerships Further funding and public-private partnerships are essential to integrate advanced technology in the food retail sector. By investing in technology, we can drive sustainable practices in retail, making it easier to monitor and manage food waste effectively.
- Enhance Data Reliability and Standardization for Food Waste Measurement. Reliable, standardized data on food waste is crucial for designing effective solutions. Increased research and investment in food waste quantification methods are necessary, along with exploring adoption challenges and gaps in existing standards. Accurate data will better inform policy and facilitate the adoption of advanced technologies like dynamic pricing in retail.
- Promote Economic Incentives for Food Waste Reduction in Retail Retailers are crucial in food waste reduction due to their central position in the food supply chain. Economic instruments like subsidies for sustainable retail practices and implementing an emissions permit system at the retail level can encourage sustainable practices, benefiting consumers and producers.

5 – Crop diversification

- Develop tools for value chain coordination, partnerships and sharing of investment risks and costs towards crop diversification
- Identify key factors, crops and farming practices for successful diversified systems and investigate the variability behind diversification success
- Study and develop novel pest management approaches and products relevant for diversified systems and describe scenarios of uptake.
- Deepen scientific knowledge of the ecology of diversified cropping systems.
- Assessment of costs and benefits of innovative farming practices

6 – Nitrogen

- Interdisciplinary policy-relevant research on societal barriers and opportunities for large-scale introduction of known sustainability solutions addressing nitrogen and interconnected issues.
- Improved quantification of nitrogen flows in current and possible future agri-food systems, and of remaining uncertainties.
- Fundamental advances in selected biogeochemical complexities.

7 – EU Africa cooperation

- Enhance alignment of EU R&I programs with local needs and policy environments in African countries.
- Foster market-driven approaches, including startup support and private-sector partnerships.
- Scale up blended finance and other innovative funding models to drive adoption.
- Strengthen platforms for knowledge exchange, monitoring, and learning across stakeholders.
- Incorporate mechanisms to better evaluate and replicate successful interventions in future programs (e.g., FP10).

8 – Transformative innovation

- Develop systemic and context-specific solutions that integrate ecological, technological, social, and institutional dimensions.
- Enhance stakeholder engagement in research processes to align innovation goals with societal values and needs.
- Investigate the interplay of short-term crisis management and long-term ecological goals to strengthen resilience.
- Promote new narratives for food system transformation that inspire action and build consensus across diverse sectors.



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