EU CAP NETWORK

EU CAP Network seminar

Smart circular farming to address high energy and fertiliser prices

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Introduction

Background

In response to the impacts of the climate crisis and, more recently, the economic consequences and disruptions to food supply due to the outbreak of the COVID-19 pandemic and Russia's war in Ukraine, the prices for agricultural inputs and products have been driven upward. This contributes to the increased vulnerability of food systems and threatens food security in the long-term. Trade disruptions, transportation costs and uncertainties regarding global agricultural markets highlight the dependency on agricultural inputs and commodities. Uncertainties related to energy and fertiliser exports from Russia in particular are putting severe pressure on agriculture and food production in Europe.

The current crisis underlines the urgency of efficient and sustainable use of energy and fertilisers to ensure farm resilience, competitiveness and food security during times of high-priced inputs. Innovative solutions are necessary in order to overcome the current deficits in energy availability and the availability of affordable and sustainable fertilisers. These solutions need to focus on using local resources efficiently, reducing input requirements for production and recycling agricultural wastes and by-products. This would create a more circular approach, with great benefits for the rural economy and ensure a transition towards more sustainable ways of food production.

Knowledge and innovation are essential components in lowering consumption of increasingly scarce resources. Collaboration across sectors and among different stakeholders are key to bringing sustainable solutions from the lab to the ground. The increased availability of data and its use through ICT, IoT, predictive tools and precision technologies can allow resources to be targeted in a more effective and efficient way.

To address the current challenges that seriously affect food production in Europe and farmers' economic integrity, on 6 and 7 December 2022 the Directorate-General for Agriculture and Rural Development of the European Commission together with the Support Facility for Innovation and Knowledge exchange including EIP-AGRI, held in Porto, Portugal, the EU CAP Network seminar 'Smart circular farming to address high energy and fertiliser prices'. Unpredictable price volatility on the energy and fertiliser markets called for the organisation of this event in order to contribute to overall efforts to safeguard food production and distribution in Europe.

Overall aim of the seminar

Circular economy approaches in agriculture strongly rely on circular thinking of farmers and other rural stakeholders. They involve looking for ways to reduce waste and increase efficiency, using resources more sustainably, and creating synergies between different parts of the agricultural system. Circular thinking encourages farmers to think in terms of 'closing the loop' and finding ways to reuse and recycle resources while minimising their environmental impact. Circular thinking also encourages farmers to look for ways to diversify their farm activities and develop new markets. Finally, circular thinking for farmers can mean engaging with the communities around them, looking for ways to collaborate, and working together to create a more sustainable and sovereign food system.

With this in mind, the overarching aim of the seminar was knowledge exchange to find and mainstream innovative solutions to respond to decreasing accessibility and affordability of energy and fertilisers. The objective to achieve this was by building resilient farming and food systems through smart circular economy approaches at farm and local level to safeguard food security and climate objectives.

Specific objectives of the seminar

The specific objectives of the seminar were to:

- Exchange knowledge on successful practices, opportunities and tools relevant for maintaining and enhancing energy security and fertilisers availability and affordability through a circular approach, and specifically on:
  - Increasing self-sufficiency
  - Increasing resource efficiency and sustainability
  - Reducing greenhouse gas emissions
  - Enhancing cooperation at both farm and local level
- Identify challenges caused by lack of energy security and explore potential solutions
- Identify needs from practice and possible knowledge gaps and possible directions for further research
- Promote networking among EIP-AGRI Operational Groups and other innovative projects and relevant stakeholders

Participants

The seminar was designed as a multi-stakeholder event, welcoming farmers, advisors, scientists, and other actors from the supply chain, farming associations and chambers, local authorities etc.

In total, 101 delegates from 23 European countries participated in the seminar. The biggest group of participants were researchers (33). This was followed by experts from an association, network, group or enterprise (25). Out of all participants, 23 were farmers, farm managers or land owners. Several participants belonged to more than one group.

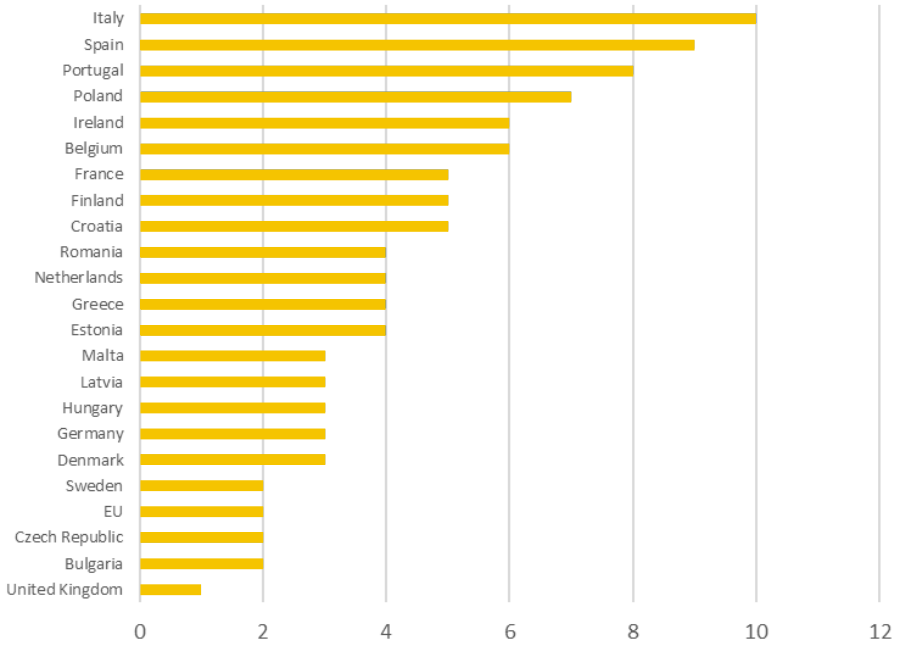

Figure 1 Participants by country of origin

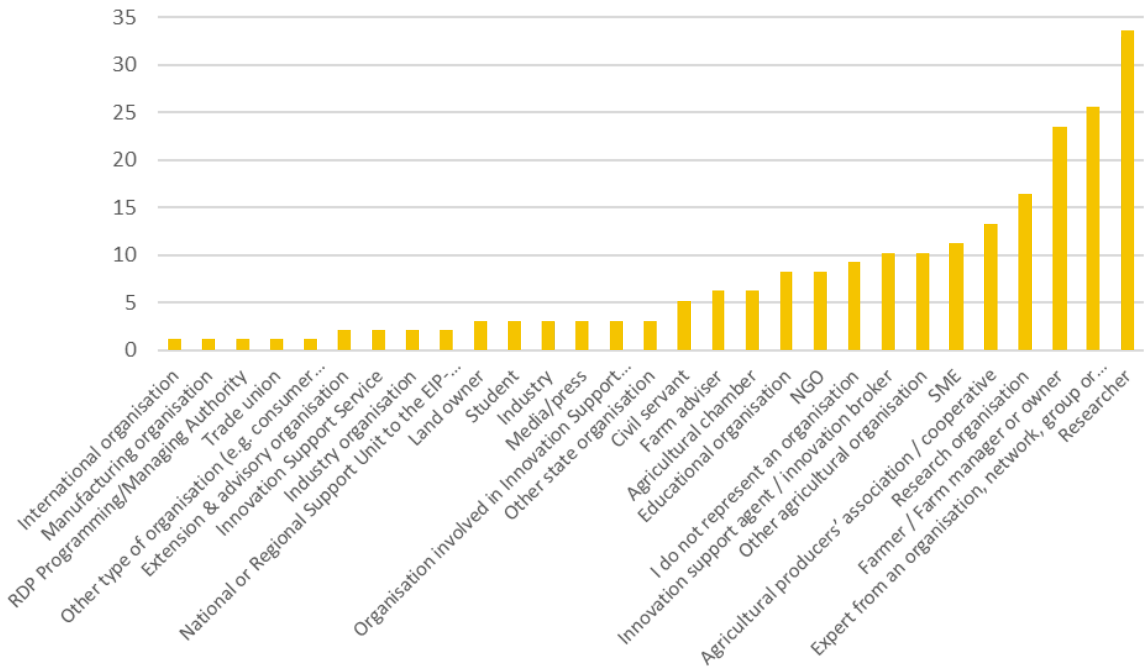

Figure 2 Participants by professional background

Interactive workshop methods

The whole seminar was designed to facilitate communication and knowledge exchange among the participants and to encourage active involvement and engagement. The reason for using interactive workshop methods including collaborative working in breakout sessions was to encourage creative thinking and harvest ideas and solutions quickly. Therefore, a structured set of facilitated activities was elaborated, based on predefined questions to explore challenges and solutions. The seminar started with a plenary session to set the scene and to provide essential background information about the situation of agriculture and food production in Europe and the implications of volatile input prices for food security. Then, the participants were invited to get to know each other by a facilitated ice-breaking session. A series of short inspiring presentations provided examples of real-life solutions which showcased circular approaches to overcome resource dependencies.

The first breakout session was designed to build upon the inspiration from the presentations. Participants were invited to work on the following questions:

- How to identify promising solutions to overcome energy and fertiliser depletion that already exist?
- How to mainstream existing solutions to overcome energy and fertiliser depletion?
- How to establish functional knowledge networks on circular approaches to resource use at local level?
- How to mainstream circular economy approaches in agriculture and food systems to overcome current and prospective energy and fertiliser shortage?
- How to address current and prospective resource depletion and maintain sustainability?
- How to reduce trade-offs between productivity and sustainability when dealing with resource shortage?

The second breakout session was run as a world cafe, in which the participants were invited to work on four main themes:

- Reducing dependencies
- Required support
- Crucial challenges
- Cooperation and collaboration

The afternoon was reserved for field visits to see practical examples of circular approaches in the area. Communication among participants was facilitated on each bus ride to encourage participants to get to know each other better. The evening was reserved for a networking dinner in order to further facilitate discussions on the topic in a more informal atmosphere.

The second seminar day started with a general feedback session on the field visits in the plenary. Then, participants were invited to showcase their own projects which were displayed as posters on the wall of the plenary and to discuss them with interested participants. This session was followed by another breakout session in which participants worked on three key aspects:

1. Increasing resource efficiency and sustainability
2. Enhancing cooperation at both farm and local level
3. Enhancing cooperation along the value chain

Back in the plenary, participants then shared key insights from the whole seminar, gave feedback and evaluated the seminar organisation and content and at the end of a fruitful seminar, the organisers delivered the closing remarks.

The outcomes of the discussions were documented on flip chart posters and were displayed after each breakout session on the walls of the plenary room so that participants could easily review the results. After the seminar, all posters were transcribed and formed the basis for elaborating this final report.

Proceedings

Setting the scene

- **Wolfgang Burtscher**, Director-General of DG Agriculture and Rural Development (DG AGRI), European Commission (video message)

Wolfgang Burtscher welcomed the participants and introduced the current context of high energy and fertilisers costs. In this regard, he highlighted the timely opportunity that this seminar presented to exchange knowledge on successful practices and tools relevant for energy security, fertilisers availability and affordability, and also to discuss and identify innovative solutions for resilient farming and food systems through smart circular economy approaches. The Director-General underlined that even though the crisis presents many challenges, this is also an opportunity to accelerate the transition to more sustainable food systems, reduce our dependency on fossil fuels and improve fertiliser use efficiency and reduce nutrient losses. To properly seize this opportunity both the current and future Common Agricultural Policy can provide the support for on-farm or collective investments in renewable energy, in the use of renewable energy in smart villages, biogas installations and for advisors and innovations.

- **Michael Wolf**, research policy officer, DG AGRI, unit F.2 Research and innovation, European Commission - Presentation

Michael Wolf introduced the current crisis and its impact on everyday farming. The European Union is highly dependent on imported fertilisers and on energy to produce them. High prices for farm inputs are a significant concern for farmers and policy makers because they affect the farmers' capacity to purchase fertilisers, feed and other farm inputs and to pay their energy bills, this potentially adds to concerns about food affordability. Thus, in order to unleash the potential of a fossil-energy-free agricultural sector in Europe, renewable energy produced by the agricultural sector must be promoted. Technical complexity must be reduced to develop cost effective solutions for de-fossilised agriculture.

Inspiring examples

- **Elisa Pellegrino**, Fertibio - Microorganisms in Support of Agriculture - Presentation

Fertibio is a project specialising in the development of products, services, and technologies that use microorganisms to improve soil fertility and crop productivity. The products are designed to increase the availability of nutrients in soil, reduce the need for chemical fertilisers, and promote more sustainable agricultural systems. Fertibio offers a range of products, including biological inoculants, organic fertiliser, and soil amendments.

- **Konstantinos Vaiopoulos**, Agrofossilfree - The path towards a fossil-free EU agriculture - Presentation

Agrofossilfree is a project that seeks to reduce the EU's dependence on fossil fuels for agricultural production and to support the transition towards a more sustainable and fossil-free agriculture in the EU. The project promotes Fossil-Energy-Free Technologies and Strategies (FEFTS) by assessing the energy status of EU's agriculture and farmers' needs, developing a knowledge platform for providing information on FEFTS, incentivising innovation through multi-actor networking, innovation workshops and providing policy advice.

- **Wouter Merckx**, HyPErFarm – Hydrogen and photovoltaic electrification on farm - Presentation

The project is based on a multi-actor approach including research, industry and farmers and aims to demonstrate effective decarbonisation of farms by agrivoltaics while maintaining crop yield. HyPErFarm is focused on combining hydrogen production and photovoltaic (PV) technology to provide clean, renewable and efficient energy solutions for farm electrification in rural areas.

- **Maria Rosa Mosquera-Losada**, GO-Grass - Grass-based circular solutions for rural agri-food value chains - Presentation

GO-Grass is a European project that aims to develop circular solutions for rural agri-food value chains, with a focus on grass-based systems by unlocking the grass-based biomass potential to create additional business opportunities for farmers in rural areas. The projects' focus is on producing biochar from late harvest cuttings, making paper and packaging from roadside and nature conservation grasses, manufacturing bedding material for animals using briquetting technology and producing grass protein powder as feed for monogastrics and poultry.

- **Stamatia Petridou,** Since-AFC - Exploring the unlimited potential of Agrifood sector in Circular Economy - Presentation

The project aims to improve policies in the field of regional innovations strategies by facilitating horizontal mechanisms that support and enhance SMEs entrepreneurship in the Agri Food sector through the exploitation of circular economy opportunities.

Therefore, the project concentrates on interregional learning processes, the identification of good practices, the design and set-up of action plans and policy change.

Breakout session 1: Developing solutions

The participants were split into six breakout groups to facilitate deep discussions, responding to specific questions addressing the energy and fertiliser shortage. The main idea was to identify and further develop existing solutions. This interactive session was designed to capture and document the delegates' points of view.

Addressing resource depletion while maintaining sustainability

Addressing current and prospective resource depletion while maintain sustainability is a pressing concern within the agricultural sector. Renewable energy sources have the potential to significantly reduce dependence on non-renewable sources of energy.

One of the most effective ways to achieve balance between recycling and use in cascade is to implement a tiered approach to resource management. This approach would involve maximising the use of recycled materials for lower-value applications (such as packaging or construction materials). In addition, the use of renewable and non-renewable resources should be optimised to ensure that resources are used in the most efficient and effective manner possible.

Farmers can reduce their energy consumption and reliance on synthetic fertilisers by investing in renewable energy sources, utilising energy-efficient farming methods, and utilising low-energy inputs. They can increase their use of energy-saving technologies for irrigation. In addition, participants stressed the example effect of organic farming and other sustainable agricultural approaches including practices such as intercropping, cover crops, green manure, agroforestry practices, composting, and vermiculture. Further, farmers could invest in improved cold storage and post-harvest handling systems, and renewable energy technologies such as biogas plants.

Solar energy and agrophotovoltaic (APV) can help to address resources shortage for agriculture and food production in a number of ways. By harnessing solar energy, APV can provide energy to power water pumps, heating and cooling systems, and other equipment necessary for agricultural production. Solar energy can also be used to power greenhouses or processing facilities.

Biogas and biomass are two renewable energy sources that are becoming increasingly popular as we move towards a clean energy future. Investing in these technologies can provide a number of benefits, from reducing emissions to creating green jobs. Biogas is produced by breaking down organic matter, such as food waste or animal waste, and converting it into a gas that can be used for energy. Biomass (solid biofuels) as a primary source to generate energy, on the other hand, relies on organic materials, such as wood, green municipality waste or crop waste.

Smart fertilisation was mentioned during the seminar as solution for fertiliser shortage. It refers to the use of technology to automate and optimise the application of fertiliser to agricultural land. This technology can help farmers reduce their use of chemical fertilisers, helping to reduce environmental impacts, reduce costs while maintaining crop yields. Smart fertilisation systems use sensors, computer algorithms, and other technologies to monitor soil conditions and apply the right amount of fertiliser at the right time. Nutrients for fertilisation can be recovered from bio-waste using a number of methods. Recycling methods that can be used to recover phosphor from bio-waste for example include thermal recovery, gasification, and anaerobic digestion. Another method is entomo-composting, which uses the black soldier fly. Furthermore, extraction of the excess phosphor in the slurry can then be used to produce the raw material for organic fertilisers. Introducing microbial and non-microbial plant biostimulants can help to fix nutrients in the soil, making it accessible for plant uptake. For example, yellow lupine can be used to make fixed phosphor accessible and to collect nitrogen from the atmosphere.

Biochar-fertiliser mixtures are mixes of biochar, a type of charcoal created from the burning of biomass, and other fertilisers.

Biochar is used to improve soil fertility, as it increases soil organic matter, providing a source of nutrients for plants and microbes. When it is mixed with fertilisers, biochar can improve the efficiency of fertiliser use, reducing the amount of fertiliser needed to achieve the desired effect. Additionally, biochar can improve the water-holding capacity of the soil, reducing water runoff and thereby improving crop yields.

Possible sources for recycling biogenic resources:

- Municipal solid waste (MSW)
- Composting facilities
- Local farms
- Biogas digesters
- Industrial food processors
- Animal feeding operations
- Commercial composters
- Renewable energy facilities
- Bio-refineries
- Waste management centers
- Schools
- Hospitals

The recovery of nutrients from municipal wastes can be done in a variety of methods. One way is through composting. Additionally, anaerobic digestion can be used to produce biogas for energy purpose and a nutrient-rich digestate that can be used as a fertiliser. Lastly, nutrient recovery systems such as membrane bioreactors, ion exchange filtration, and reverse osmosis can be used to recover valuable nutrients from wastewater.

Certification of organic fertilisers was mentioned as a ground-breaking approach to promote the use of sustainable and environment-friendly fertilisers. Certification needs to focus on a number of key areas, including avoidance, of fossil-based fertiliser nutrient loss avoidance, and utilisation of bio-residues, by-products and bio waste, and optimisation of fertiliser use.

Reducing trade-offs between productivity and sustainability

Reducing trade-offs between productivity and sustainability in agriculture involves finding ways to increase agricultural production without compromising its environmental or social impact and at the same time maintaining or even increasing farm income. The main strategies identified by participants were:

1. Increase energy efficiency
2. Reduce fertiliser use
3. Promote sustainable agriculture practices and organic farming

To reduce the trade-off between productivity and sustainability, a holistic approach is needed. This requires disseminating and implementing best practices in efficient resource management and use, by utilising precision agriculture, integrating agroecological practices, and increasing education and awareness. Precision agriculture and smart farming approaches, such as satellite-based remote sensing and variable rate application (VRA), in particular can help to reduce inputs while maintaining yields. Agroecological practices such as using locally available organic fertiliser, crop rotation, intercropping, planting green manure and increasing agroforestry areas can help to guarantee productivity while also promoting long-term farm sustainability and resilience.

Improving education (agroecological literacy) and investments into awareness building strategies about sustainable farming practices and resource management can help farmers understand the importance of sustainability and the interplay between productivity and sustainability.

Checking the feasibility of the proposed solutions to reduce trade-offs between productivity and sustainability at farm level involves assessing the availability of resources as well as assessing the financial costs, the environmental impacts, and the potential for success.

Functional knowledge networks on circular economy approaches

Functional knowledge networks on circular approaches to resource use at local level can be created by connecting local stakeholders, such as farmers, local businesses, local governments, and community organisations. EIP-AGRI Operational Groups (OG) and LEADER's Local Action Groups (LAG) can help to catalyse circular economy approaches at local levels. These networks can be used to identify and develop innovative solutions to resource use challenges, such as local waste management or energy efficiency.

Availability and access to specific information about local resources is crucial to build a solid knowledge base on sustainable circular approaches to manage renewable and recycled resources. Therefore, providing opportunities for networking and sharing experiences by developing digital knowledge exchange platforms, geared to local circumstances, for sharing experiences about local experiments and innovation to address energy and fertiliser shortage, might help to disseminate best practice examples and at the same time contribute to reducing risks related to the introduction of new technologies or methods.

Such platforms are an important instrument to bridge the gap between farmers, advisors, academics, and local policymakers. National advisory systems could be integrated to act as an interface for providing support to farmers tailored to improving energy use and nutrient management.

A virtual demo farm hosted by such platforms, would be a digital playground that enables farmers, food producers, and retailers to collaborate and take advantage of and test circular economy practices.

Easy to use knowledge network

- Develop a solution register
- Disseminate best practice solutions
- Connect the platform to advisory systems
- Organise live events (workshops, seminars,...)
- Establish demo sites (living labs)

Digital platforms can also help farmers and researchers communicate more efficiently with one another and can lead to more fruitful collaborations. These platforms could include links to applications and websites that provide further access to information, resources and assistance. Probably the most relevant benefit of such a platform is the local coordination of supply and demand of available resources. However, digital platforms cannot substitute face-to-face networking events for exchanging experiences and innovations. Presenting best practice examples in person and providing opportunities for lively discussions, including possibilities for asking questions and clarifying doubts, can boost the dissemination of innovations. Practical demonstrations of project results particularly enhances the credibility of results and increase adoption rates.

To ensure that farmers have access to the benefits of modern technology, it is necessary to provide support and training. This can include resources such as tutorials, educational materials and seminars to help farmers understand how to best use digitalisation and robotics to increase their productivity and efficiency. Additionally, it is important to provide support for the technical aspects of digitalisation and robotics, including troubleshooting, maintenance and repair.

Mainstreaming circular economy approaches to overcome current and prospective energy and fertiliser shortage

Creating awareness about the solutions and developing systems to ensure access to these solutions can be done through traditional media like television, radio, news, etc. In addition, social media should be actively promoted to share best practice experiences. Local dissemination structures need to be strengthened to enable project stakeholders to communicate their outcomes and farmers to share their experiences. Such structures could be networks of living labs and demo sites at farm level.

Demo farms could demonstrate how to use energy and fertiliser efficiently and effectively by providing hands-on training and educational resources. Lighthouse farms could demonstrate the benefits and opportunities of using sustainable energy and fertiliser practices. Whereas, living labs provide an area where farmers can receive training on energy efficiency and organic fertiliser use while also carrying out research on new technologies. In addition, farmer to farmer knowledge exchange is an important part of the solution, as it allows farmers to share their experiences and knowledge with each other. By using these existing solutions, governments, NGOs, and other stakeholders can work together to help farmers reduce their energy and fertiliser use and find viable alternatives.

Digital technologies can help farmers manage their land in an efficient and sustainable way. For example, digital mapping systems or remote sensing allow farmers to monitor their crops and soil composition in real-time, and precision agriculture systems provide detailed data on soil moisture, crop growth and yield, and the spread of pests and diseases.

Digitalisation in agriculture

- Precise irrigation systems
- Optimising energy production and consumption
- Optimisation of inputs (nutrients/water)
- Monitoring of crop and livestock health
- Precision farming
- Smart farm automation
- Weather forecasting and monitoring
- Soil mapping and analysis
- Drone-based crop monitoring and treatment
- Predictive analytics and decision support systems
- Robotics and Artificial Intelligence applications

A key aspect for mainstreaming circular economy approaches is broad diffusion of relevant information by building an easily accessible, user-friendly and ready-to-use knowledge sharing platform. An internet-based digital knowledge platform, as mentioned before, could help to organise and coordinate local events where stakeholders can meet in person to discuss specific local challenges and find appropriate solutions for the local context. In addition, such platforms can be enhanced with Artificial Intelligence (AI) or voice-assisted search capabilities.

Education programmes and outreach initiatives to raise awareness around the issue could also be effective in promoting sustainable solutions and helping to overcome energy and fertiliser depletion.

Identifying promising solutions to overcome energy and fertiliser depletion

Scientific research and local experts hold a key position for identifying and disseminating viable solutions to overcome energy and fertiliser shortage. Available sources for producing renewable energy and substituting synthetic fertilisers must be identified bearing in mind local conditions. Sustainable energy sources include solar power, water, wind or geothermal energy. By using these energy sources, animal manure, agricultural waste, food waste and by-products from food processing can be used to produce bio-based fertilisers and extracting nutrients.

Sustainable technologies such as agro-photovoltaics and their synergies with combined cultivation, hydropower, wind power, solar power, geothermal power and anaerobic digestion need sustainability and economic assessment conducted by scientists or other local experts for estimating environmental impacts, economic feasibility and efficiency. In addition, research needs to evaluate promising solutions based on their potential for scalability, and cost efficiency.

Mainstreaming existing solutions to overcome energy and fertiliser depletion

There are a variety of existing solutions to overcome energy and fertiliser depletion. Mainstreaming these solutions requires raising awareness among farmers and decision-makers about sustainability and circularity in agriculture and the linkage to resource depletion, as well as providing incentives and other forms of support to encourage their adoption.

Finally, currently there are many online resources and courses available for farmers to learn more about agricultural innovation to address farm specific challenges. Developing and providing educational materials, such as webinars, video tutorials, podcasts, and fact sheets, helps disseminate knowledge about circular economy and sustainable agriculture.

The most effective way to mainstream existing solutions to overcome energy and fertiliser shortage is by improving the knowledge of policy makers. They should also be educated on the importance of investing in sustainable, renewable and locally available energy sources, and on the potential of organic farming and other sustainable agriculture approaches as a means to replenish soil fertility and reduce the need for fertiliser. Additionally, policy makers should be encouraged to provide incentives to farmers to adopt sustainable practices and technologies. Finally, policy makers should be made aware of the need to develop new technologies that can provide solutions when faced with energy and fertiliser shortages.

Breakout session 2: Learning from each other

For the second breakout session, the participants split up into smaller groups to facilitate discussions. Each group was invited to explore the four key questions together from the perspective of energy shortage and fertiliser depletion. Participants were encouraged to move around between the groups in world café style to share their expertise. The outcomes of each breakout group were captured on flip chart posters.

How can we reduce dependencies on energy or fertilisers while maintaining productivity and food security at farm level?

One way to reduce dependence on energy while maintaining productivity, sustainability and food security at farm level is to focus on regenerative farming techniques. This involves techniques such as cover cropping, conservation tillage, crop rotation, and manure and compost management which can help to restore and maintain soil fertility.

Practices such as drip irrigation, mulching, and use of low-powered farming machinery can also help minimise energy use in the farming process. In addition, farmers could integrate agroforestry into their farming systems to diversify production and for carbon sequestration. Farmers could be encouraged to utilise renewable energy sources, such as solar and wind, to power their operations and reduce their dependency on fossil fuels, in order to guarantee production even in times of crisis.

Approaches for local energy management

- Focus on waste streams and by-products
- Produce locally - use locally
- Attention: food crops vs. energy and biofuel crops
- Increase efficiency (Precision farming, Smart farming, robotics)
- Downsize machinery and equipment
- Produce green hydrogen power
- Produce clean energy at farm level for self-consumption
- Reduce energy requirements for farm machinery and equipment

Whenever using renewable plant resources, 'cascading use' should be applied. The primary use should be reserved for food production or for animal feed. The secondary use is then for energy production, such as for biogas, bioethanol, or pellets. Additionally, the use of biomass in a cascade has a number of environmental benefits, including the preservation of biodiversity, carbon capture, and the recycling of nutrients and therefore is becoming increasingly popular as an alternative energy source. This technique can help increase the productivity and profitability of a farm, as well as reduce environmental impact. For example, a farmer may grow corn for food and also use the stalks and cobs for biofuel production.

In agriculture, alternative fuels can be used to power farm equipment such as tractors and combines. Biofuel made from renewable sources such as vegetable oils, animal fats, and recycled restaurant cooking oil and grease should be further developed. Ethanol, a renewable fuel made from corn and other plant materials, can be used to power both tractors and combines but cascading use should be applied to avoid competition between food and fuel production. Additionally, electricity is becoming increasingly popular as a source of power for agricultural machinery. To increase long-term farm sustainability and to reduce dependencies on external inputs, horse power should not be underestimated. Horse power can also be used to operate machinery and irrigation systems, resulting in lower input costs for farmers.

Technologies for local decentralised energy production

- Solar Energy
- Agro photovoltaics
- Wind Energy
- Micro-Hydro Power
- Biomass
- Biogas
- Geothermics
- Waste-to-energy systems
- Green hydrogen

Creating a network of small-scale, decentralised biogas systems in rural areas close to farming communities contributes to local energy sovereignty. Such biogas systems would use locally available organic waste to generate renewable energy and fertiliser for agricultural use. The small-scale nature of such systems would allow for easy set up and maintenance, while providing local communities with an affordable and sustainable energy source. Additionally, the biogas systems would create economic opportunities for local farmers and help reduce greenhouses gases associated with energy production.

Local natural resource optimisation is the practice of managing, protecting and improving the sustainability of local natural resources. This includes natural resources such as water, soil and land, and improving the productivity of these resources to ensure their long-term sustainability and benefit to their local community. Local natural resource optimisation can involve activities such as conservation, reforestation, watershed management, habitat protection and restoration, and responsible resource extraction.

Optimisation of production processes could be achieved through a variety of measures, such as reducing the energy and resource use, increasing the efficiency of energy and resource use, or reducing the rate of consumption. Technology can help in this regard, but it should be used cautiously to avoid creating new dependencies on unsustainable technologies. Creating economic space for change by incentivising sustainable practices through subsidies in green technologies can help to ensure that these practices become the norm. Synergies between technology and nature should be explored and strengthened to ensure that technological developments are used to enhance, rather than disrupt, natural ecosystems. Local food sovereignty should be prioritised over the comparative advantage of large corporations.

Addressing fertiliser shortage

- Use crop rotation and intercropping
- Plant green manure and cover crops
- Adopt conservation tillage
- Promote integrated nutrient management
- Use compost and other organic fertiliser
- Utilise micronutrient fertilisers
- Use bio-stimulants
- Use biochar to capture nutrients
- Develop crops that are more responsive to fertilisers
- Increase use of precision farming
- Practice effective soil testing

What are the crucial challenges that might be encountered?

One of the most crucial challenges in addressing energy and fertiliser shortages is finding sustainable sources of energy and fertiliser. Currently, most of the world's energy and fertiliser is derived from finite sources such as fossil fuels. These sources are not suitable for long-term use. Another challenge is improving energy and fertiliser efficiency. This means finding ways to reduce the amount of energy and fertiliser needed to produce the same amount of food, while simultaneously guaranteeing crop yields. Unfortunately, the current situation has left many farmers in a vulnerable position due to their reliance on external energy sources. The trend of monopolisation on the energy market has created an unstable and costly environment for farmers. Additionally, many farmers lack the necessary financial resources to invest in energy efficient technologies, which further increases their vulnerability.

Farmers' attitudes play a major role in reducing dependencies on energy and fertilisers. The lack of cooperation might hamper cost efficient use of specialised equipment and machinery. Farmers' reluctance to increase on-farm sustainability by implementing more ecologically sound farming practices derived from organic farming or agroecology, makes the transformation towards circular economy approaches in agriculture complicated and time intensive. Awareness raising focused on the right target groups is necessary to overcome these challenges. Another crucial challenge is the lack of knowledge about renewable energy sources, agroecological farming practices and innovative sustainable technologies such as precision or smart farming that are suitable to address energy and fertiliser shortages. In addition, a lack of awareness about the interaction between environmental impacts and food production lowers the willingness to modify production methods. For specifically, a lack of best practice examples at local levels and a lack of opportunities for knowledge sharing lowers the innovation potential. Limited opportunities for farmers to engage in participatory research projects and conduct supervised field trials, hampers co-creation of knowledge which could address energy and fertiliser shortages. Furthermore, communication strategies to disseminate promising solutions are insufficient.

To improve farmers' digital literacy, training for farmers should concentrate on:

- Digital technology for sustainable farming
- Precision agriculture
- Smart farming
- Automation and robotics
- Artificial intelligence
- Internet of things (IoT)
- Big data for sustainable farming

High investment costs, the associated financial risks for specialised machinery, equipment and infrastructure and the lack of financial support for investments represent another major challenge that impedes large-scale transformation towards circular agriculture and sustainable food systems. In addition, legal constraints and bureaucracy to get permits can affect the innovation capacity at farm level (for example permits for building specialised infrastructure or for testing nutrient recycling from agricultural waste and by-products).

What kind of support do farmers need?

Innovation training for farmers can be provided in a variety of ways. One approach is to offer workshops or seminars that provide an overview of the latest technologies, trends, and methods used in agriculture. These could include topics such as precision agriculture, integrated pest management, and agroecology. Additionally, seminars can provide an opportunity for farmers to elaborate their own ideas, to network and share best practices.

Another approach would be to provide hands-on training that focuses on specific innovation projects. These could include demonstrations of new technologies such as smart irrigation systems, high-tech greenhouses, or robotic harvesting systems. This training could also involve developing marketing plans, exploring new ways to guarantee productivity, or creating new value-added products.

Designing and developing a training course for farmers could help to mainstream circular economy approaches in agriculture. Similar to training courses for farmers, training courses for municipality staff should also be developed and provided.

Supporting the transition towards a more sustainable agricultural system, requires more financial support for farmers to invest in renewable energies and use bio-based fertilisers. This could include improved financial advice for farmers to promote investments in renewable energy such as agro-photovoltaic, geothermal energy, small hydro power plants, and wind energy. Furthermore, multi-funding models, low-cost solutions, and subsidies for adopting innovative solutions to reduce fertiliser use could be implemented. Furthermore, local investment strategies for circular economy approaches in agriculture should be improved by, for example, facilitating the creation of energy cooperatives with citizen involvement.

To ensure farmers' access to the best agricultural practices and technologies, technical support needs to be improved and upgraded. This should include personalised advice and training on sustainable agriculture practices, the use of bio-based fertilisers and the potential of renewable energy production.

Policy support is crucial to promote sustainable agricultural practices, the use of bio-based fertilisers and renewable energy. Apart from adapting regulations to foster circular economy approaches, farmers need incentives to adopt sustainable agriculture practices.

Which types of cooperati on and collaboration facilitate circular economy approaches?

Local cooperation and collaboration is essential for the successful implementation of circular economy approaches. Different stakeholders, such as local governments, businesses, universities, research institutes, NGOs, and citizens must work together to create an effective system. Including a variety of relevant stakeholders can contribute to disseminate knowledge and technology needed to overcome prospective energy and fertiliser shortage on large scale level.

The effective implementation of a bioeconomy requires the cooperation of all stakeholders within a value chain. Incentivising cooperation among farmers or cooperatives, technology providers, energy companies, biowaste managers, food and feed companies, logistics companies, and retailers is essential in order to successfully transition to a circular bioeconomy.

Promoting cooperation:

- Promote setting up of Operational Groups (OG)
- Facilitate bottom-up approaches for addressing local challenges
- Foster small local cooperatives
- Work with local stakeholders
- Provide collaborative training
- Integrate the consumer perspective
- Horizontal and vertical cooperation

Participants also suggested incentivising cooperation across all stakeholders in the value chain from farmers to food and feed companies, technology providers, biowaste managers, energy companies, and logistics companies. Networking between existing cooperatives, farmers associations, local initiatives for plant breeding, and links to consumers should be strengthened. Participants also suggested education, advisory, and capacity building adapted to different regional conditions, and facilitation of dissemination of best practices. Additionally, horizontal and vertical cooperation between livestock and arable farmers, municipalities, and foresters should be promoted.

For example, energy cooperatives can be set up between local governments, farmers, and citizens to work together to produce and share renewable energy. Similarly, fertiliser cooperatives between farmers and local governments could be promoted to produce fertiliser from municipal organic waste.

Shared infrastructure at community level can help to facilitate more efficient use of resources derived from agricultural production or food systems waste by promoting circular economy approaches. Examples of shared infrastructure include community composting facilities, shared agricultural equipment and tools, shared greenhouses and cold storage, and shared irrigation systems. Additionally, shared infrastructure can reduce the costs associated with purchasing and maintaining equipment. Machinery sharing and rental services can be mainstreamed by encouraging farmers to make use of such services or by providing subsidies or incentives for establishing and using such networks.

Co-creation of solutions and innovations through collaborations between different stakeholders, such as industry and research, is another promising approach to mainstreaming existing solutions to deal with energy and fertiliser depletion. Additionally, research and development of new technologies could support the transition to more efficient and sustainable use of energy and fertiliser. Another way to address energy and fertiliser shortages is through a multi stakeholder approach such as EIP-AGRI Operational Groups. These projects bring together a variety of stakeholders such as farmers, scientists, advisors, agricultural experts, industry or government representatives, NGOs, and other relevant actors to develop and implement practical solutions. These stakeholders work together to identify the most pressing needs and develop solutions ready to implement in practice.

Field trips

Two different field trips were organised close to the seminar venue to see practical examples of circular economy approaches in agriculture to address high energy and fertiliser prices. Participants were able to choose one of two options. The bus ride provided further opportunities to deepen professional discussions among the participants.

Field trip 1

BioChorume

This field visit started with a presentation of the AVELEDA Company explaining what led to the creation of the BioChorume OG. Then the company Fertiprado presented its approach to develop and test pre-inoculating leguminous seeds.

Livestock effluents (slurry) can provide a good alternative to mineral fertilisers, not only from an economic perspective, but also from the point of view of soil fertility and farm resilience. In the BioChorume OG, the effect of increasing doses of slurry on tree growth was evaluated in clones of Paulownia and Populus, as they have a high efficiency in the mobilisation of soil nutrients and in the capture of CO2 from the atmosphere, as well as high biomass calorific value. A demonstration field was visited where different treatments, either with or without inoculation prior to transplantation, of mycorrhizal arbuscular fungi and plant growth-promoting bacteria were being tested. Results showed a positive effect of the slurry application, showing its fertilising potential which should later be assessed on its ability to constitute an alternative or, simply, a complement to mineral fertilisation.

Ecoseed Fertiprado

The project Ecoseed - Optimisation of the seed microbiome to obtain fertiliser phenotypes adapted to climate change focuses on developing mixtures of seeds for pasture with the main objective of using soil microorganisms, such as nitrogen-fixing bacteria in symbiosis with legumes and other types of bacteria that promote plant growth in association with Graminae plants. The goal is to design innovative inoculants, which allow an increased plant productivity, improve soil quality and avoid the use of chemical fertilisers, contributing to reducing environmental impacts and economic costs. The microbial coatings are based on microorganisms that provide resistance to abiotic and biotic stresses in times of reduced fertiliser availability.

"The utilisation of slurry to produce biomass is a good process but the impact on the environment should be studied."

"Interesting how research on the use of manure is being used to break down boundaries to find new methods."

Participants' statements

Field trip 2

Freetilizer

During the visit, the industrial prototype of Freetilizer was presented. This visit was organised to learn about this innovative biotechnological-industrial solution focused on the profitable valorisation of organic by-products. The technology consists in the conversion of nutrients present in organic by-products, using a selection of enzymes, in a reactor with homogenisation, agitation, and controlled pH and temperature. The process ends with a vacuum drying step which results in the formation of stabilised solid and liquid organic fertilisers. The results contribute to substitute synthetic ferilisers in times of high energy and fertiliser prices. Freetilizer is a subsidiary company of Pipemasters supported by European Structural and Investment Funds.

"To discover that a metal welding company can turn into a nutrient recycling business, means that there are opportunities everywhere"

"Fascinating what is possible to get out of waste and that it is economically useful as well."

Participants' statements

Alchemy

The Alchemy project seeks to optimise the efficiency of biomolecule production and investigate new applications for the resultant by-products and residues. This could lead to the development of new molecules with high commercial value, especially in the cosmetics, industrial, food and agriculture sectors. During the visit of the Alchemy project the main steps to obtain a new product ZeoVinK were shown and results from valorising organic waste derived from fermentation were demonstrated. This process was contributes to improve circular bioeconomy approaches.

The Alchemy project involves an investment of which around 60% stem from private funding and the rest is financed through Portugal 2020 and the Operational Program of Regional Development (ERDF).

The Alchemy research project results from a strategic partnership between the Universidade Católica Portuguesa, through the Escola Superior de Biotecnologia (ESB), the company Amyris Bio Products Portugal, a subsidiary of Amyris Inc. and the Government of Portugal.

"I think the project to produce trees for biomass with slurry addition was very interesting."

Participants' statements

Showcasing project solutions

The second seminar day started with sharing reflections on the field visits from the day before. Then, participants were invited to showcase their innovative projects by presenting their solutions for addressing energy and fertiliser shortage in a poster session format. The poster exhibition helped to explore existing solutions by facilitating discussions. In total, 44 projects (Operational Groups, Horizon 2020, LIFE, Interreg and other innovative projects) were displayed and presented during this session and served as a starting point for asking questions about the projects and discussing details and feasibility. The posters are available here.

Breakout session 3: Exploring on-farm resilience

The last breakout session concentrated on successful and promising approaches to build and maintain farm resilience. Participants were invited to share their expertise on three key questions related either to energy or to fertiliser aspects. In each breakout session participants' contributions were captured on flip charts.

Energy

Increasing resource efficiency and sustainability

Energy efficiency can be improved through the reduction and avoidance of consumption and through the use of low-cost solutions such as photovoltaics for irrigation and improved management of machinery. Circular economy strategies should include compost heating systems for greenhouses, platforms for local availability of biomass resources, and ways to recycle waste products. Education and awareness should be improved through fast-tracking demo farms, integrating sustainability into educational systems, and increasing public awareness on sustainability. Finally, local production should emphasise micro electric grids, local productive networks, and the use of by-products.

Enhancing cooperation at both farm and local level

Enhancing cooperation at both farm and local level to increase on-farm resilience in case of energy shortages is a key strategy for farmers to manage energy shortages and reduce their vulnerability to climate change. Farmers can build networks and share knowledge and resources with regards to access to efficient energy sources, renewable energy, energy storage technologies, amongst others. They can also collaborate with local governments to create and implement energy-saving policies. Additionally, farmers can join local energy-efficiency partnerships to access more funding and support, such as training on energy conservation practices and access to advanced energy-saving technologies. Lastly, farmers can work together to develop energy-efficient production systems, which can help reduce energy waste and increase energy efficiency.

Enhancing cooperation along the value chain

Enhancing cooperation along the value chain to increase on-farm resilience in case of energy shortage is a strategy that could be employed to ensure the livelihood of smallholder farmers. This could involve establishing better communication channels between farmers and the buyers of their produce, such as food processing and retail companies, so that parties can exchange information on any potential shortfalls in energy and agree on solutions to mitigate any risks. This could also include bilateral contracts between farmers and buyers to provide guaranteed purchase of produce, and enabling farmers to access new sources of energy such as solar power, biogas, and other renewable energy sources.

Fertiliser

Increasing resource efficiency and sustainability

In order to increase resource efficiency and sustainability to address fertiliser shortage in the EU, uniform standards for manure use should be established. This should include providing training for farmers on nutrient management and balancing, resource management at farm level and increasing circularity of fertilisers. Other measures that should be taken are to use nitrogen fixing crops such as legumes, ban non-sustainable technologies, improve soil biodiversity and carbon storage (soil fertility), use entomo-composting, recycle human waste for nitrogen, adapt regulations, keep organic matter where it is and use effective microorganisms to improve soil fertility in the long-term. Additionally, individual composters for fertiliser production should be provided by each municipality. Finally, farmers should be educated and aware of the state of their soil and crop needs so that they can implement long-term strategies. With these measures, resource efficiency and sustainability can be drastically improved, thus addressing the fertiliser shortage in the EU.

Enhancing cooperation at both farm and local level

Cooperation between farms and the local level is essential for overcoming fertiliser shortage and for building a successful and sustainable agricultural sector. To enhance this cooperation, there are various measures that can be taken. Firstly, practical on-farm projects addressing local challenges and demonstration farms can be promoted, which can provide practical knowledge and expertise to local farmers. This can be followed by facilitated discussions between farmers and researchers. Furthermore, bottom-up approaches should be encouraged, with subsidies for circular economy projects and allowing only measures that are adapted to the local context. Additionally, local fertilisers should be produced for local farmers, using local biomass to create fertiliser. Finally, training for municipality staff and all stakeholders should be put in place to ensure successful collaboration between farms and the local level. By implementing these measures, cooperation between farms and the local level can be effectively enhanced.

Enhancing cooperation along the value chain

Cooperation along the value chain is essential for sustainable agricultural production. To maximise the benefits of cooperation, solutions to re-use heat from energy production and solutions to increase the use of bio-fertilisers need to be promoted. This can be done by promoting and fostering efforts for bio-fertiliser certification, re-creating newer smart certification systems, introducing standards for certification and sharing information about smart certification systems for bio-fertiliser. Additionally, improving access to funding, providing smart advisory on the right products for each soil type, introducing uniform standards for manure use in the EU, offering training for farmers on resource management, fostering non-commercial forms of information sharing, identifying nutrients along the value chain, and use of local waste can help. Moreover, cooperation with the fertiliser industry, and adapting legislation/regulation to permit innovation/new ideas, can further enhance cooperation along the value chain.

Research needs identified during the seminar

The participants stressed the importance of participatory and multi-stakeholder approach in research and development. Also on-farm research and co-creation of solutions was highlighted and therefore should be promoted to become the standard research strategy to improve adoptability of research outcomes. Further, communication between stakeholders is a crucial element for successful project implementation. Thus, communication strategies and discussion patterns should be optimised to develop a common language and understanding for farmers and researchers.

According to the participants of the seminar, research for maintaining and enhancing energy security and fertilisers availability and affordability should concentrate on the following domains:

- Developing new and sustainable technologies (e.g. green hydrogen, plastic alternatives, short term and long-term energy storage solutions, improving energy efficiency of machinery and farm equipment, carbon capture techniques, diversified renewable energy sources, sustainable fertilisation including renewable and recycled nutrient sources, bio-stimulants, pyrolysis, biochar, and suitability of robotics and artificial intelligence to reduce dependencies).
- Improving and increasing efficiency of already existing technology and machinery (eg. biogas production, storage solutions, solar power, water power, wind power).
- Farming system research (e.g. on-farm nutrient assessment and management, cascading production of food and energy, increasing food systems efficiency by promoting short food supply chains and localised food networks, etc.).

Idea and project market

The brokerage event after the seminar sought to address the challenge of high energy and fertiliser prices in agriculture by facilitating further networking among the participants. The event offered the space to build collaborative partnerships and to find project counterparts. The event was attended by variety of experts including farmers, researchers and advisors concerned with energy and fertiliser depletion and prospective solutions to guarantee food production under adverse circumstances. You can find the report of this event here.

Conclusion

This seminar addressed the shortage of energy and fertilisers which has been one of the most pressing problems affecting European food production since Russia started the war in Ukraine. In order to overcome resource shortages, it is essential to identify promising solutions and thereby guarantee food sovereignty and security in the long-term.

Promising strategies on reducing the intensive need for energy in agricultural production by increasing efficiency and promoting less energy intensive forms of food production based on the principles of sustainable agriculture and organic farming. Improving resource management at farm level holds a key position in addressing high energy prices. One of the most effective ways to achieve a balance between recycling and use in cascade is to implement a tiered approach to resource management. Shifting towards circular and sustainable agriculture, including the widespread dissemination of agroecological practices such as intercropping, green manure or organic fertiliser reduces the need for energy intensive industrial production of nitrogen. However, from a resilience perspective, it is crucial to ensure the primary use of plants as food, and the secondary use as biomass for energy purposes. Precision farming and smart fertilisation were discussed during the seminar as solutions for chemical fertiliser shortage. Such innovative technologies help to optimise the application of fertilisers to agricultural crops and thereby reduce environmental impacts and costs while maintaining crop yields. In addition, nutrients for fertilisation can be recovered from bio-waste using a number of methods. Introducing microbial and non-microbial plant biostimulants can help to fix nutrients in the soil, making them accessible for plant uptake. It is essential to invest in research and development to create new sustainable fertiliser and energy technologies that can be used to meet the needs of farmers. This investment will lead to the development of advanced and appropriate technologies that can be used to reduce reliance on fossil energy sources, such as oil and gas. Research should be designed as multi-actor and using participatory processes to allow end-users of technology to form part of the innovation development and solution and thereby increase impact. However, to reduce trade-offs between productivity and sustainability, sustainability assessment should be conducted by default to identify and quantify the environmental impacts associated with new technologies and products.

Diffusion of innovations should be promoted by sharing best practice examples and novice sustainable solutions. Therefore, usage of digital knowledge platforms for knowledge exchange should be promoted. Such platforms can help farmers to gain valuable insights about circularity and bio-economy issues and help to identify strategies how to address energy and fertiliser shortages at local levels and therefore should be a top priority. Exchanging experiences, ideas and resources can contribute to ensuring that farmers have the knowledge they need to shift towards sustainable agricultural practices. Furthermore, such knowledge exchange platforms can help bridge the gap between researchers, advisors, and farmers, allowing them to cooperate and collaborate to find solutions and implement them in a timely manner.

To promote circular agriculture approaches and increase the use of bio-based fertilisers and renewable energy sources, the awareness of farmers is essential. Investing in knowledge networks and education for farmers seem most promising to develop awareness about system interactions and ecological literacy in general and form a solid base for promoting agroecology, organic and sustainable agriculture. By investing in awareness building and education, farmers can gain a broader understanding of the complex relationships between the environment, plants, animals, and humans and the benefits of circular approaches in agriculture. This understanding can help farmers reduce the negative effects of unsustainable agricultural practices, such as fertiliser overuse. With increased ecological literacy, farmers can also develop and use regenerative farming practices, like conservation tillage or direct seeding to ensure their crop yields, while also reducing their environmental impact.

Finally, transformation towards a resilient society implicates a holistic approach to agriculture and food production. Economic space for transformational change needs to be created by strengthening cooperation between stakeholders and fostering local food, energy and technological sovereignty. To increase the scope of action to deal with fertiliser and energy depletion, it is necessary to reduce costs of machinery needed by facilitating machinery sharing or downsizing machinery and equipment. Furthermore, providing financial support for implementing farm-level and regional solutions reduces financial risks related to investments in new technologies.

Cooperation is necessary to strengthen the synergies within localised food and energy systems and thereby reducing negative impacts of impending and unpredictable crisis. Thus, reducing unilateral dependencies by strengthening food, technology and energy sovereignty should have a top priority.

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