

POLICY BRIEF

Bridging Digital Agriculture and Agroecology: Four Priorities for a Sustainable Transition

Authors: Andreas Meyer-Aurich; Evangelos Anastasiou; Karl Behrendt; Zhengqiu Ding; Markus Gandorfer; Spyros Fountas; Andreas Gabriel; Nicolai Fog Hansen; Alexander Häuser; Martin Hirt; Jochen Kantelhardt; Andrea Landi; Custodio Efraim Matavel; António Reis Pereira; Liisa Pesonen; Søren Marcus Petersen; Karl Reimand; Anna Rydberg; Friederike Schwier; Olivia Spykmann; Cidália Vila Verde



Executive Summary

Digitalisation is transforming European agriculture, from smart machinery, precision farming and monitoring to AI-driven decision-making. These tools can contribute to the transition to agroecology and accelerate progress towards the EU Green Deal, Farm to Fork and Biodiversity Strategies.

Yet current trends are misaligned. Most tools are optimised for efficiency in high-input, large-scale systems, with limited adaptation to agroecological contexts. Research-policy gaps, adoption barriers, unfair data governance, and weak advisory systems risk undermining the benefits.

The Coordination and Support Action D4AgEcol highlights four priorities for action:

Definition

Agroecology is a holistic approach to designing and managing food systems that integrates ecological, economic, and social principles to make agriculture more sustainable.

FAO's 10 elements provide guiding principles: diversity, co-creation of knowledge, synergies, efficiency, recycling, resilience, human and social values, culture and food traditions, responsible governance, and circular/solidarity economy.



Align digital innovation with agroecological principles: Without policy guidance, digital tools risk reinforcing high-input systems; support must prioritise ecological, social, and cultural benefits alongside efficiency.



Put farmers at the centre through participatory co-design: Adoption and effectiveness rise when farmers co-design tools. Participatory design should become the norm.



Ensure fair and transparent data governance: Farmer data rights, open standards, and cooperative governance models are essential for fair, trusted digitalisation.



Strengthen capacity and knowledge systems: Digital literacy, advisory integration, and peer-to-peer learning are the backbone of agroecological digitalisation. Without them, even the best tools will fail.

Taken together, these priorities can ensure that digitalisation supports rather than obstructs the transition to sustainable and resilient European farming.



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No.101060759. The project is co-funded by UK Research and Innovation (UKRI Reference No. 10037994). **Disclaimer:** The sole responsibility for any error or omissions lies with the editor. The content does not necessarily reflect the opinion of the European Commission. The European Commission is also not responsible for any use that may be made of the information contained herein.

Identified Issue



D4AgEcol

Background & Political Context

Digitalisation is rapidly reshaping agriculture and has the potential to contribute to more sustainable and resilient food systems. Yet the integration of digital tools into agroecological transitions remains inconsistent. While digital innovations such as precision farming, animal health monitoring, decision-support systems, and data platforms can enhance efficiency and knowledge sharing, they also risk reinforcing input-intensive practices, creating rebound effects, or widening inequalities if not properly aligned with ecological and social goals. Yet, all effects are not fully understood and require targeted research.

Farmers, advisors, researchers, policymakers, and rural communities are at the center of the digital transformation in agriculture, but they face distinct challenges. Farmers are often not convinced of the benefits of digital tools and technologies and struggle with unclear data governance and limited adaptation to daily farming practices. A lack of transparency on who controls and benefits from data reinforces power asymmetries, limiting farmer participation and trust. At the same time, policymakers need clear metrics to measure ecological outcomes and design effective support schemes, yet such indicators are often missing from current digital tools.

The usability of many digital tools remains weak: interfaces are not user-friendly, indicators relevant for agroecology are absent, and integration with advisory systems such as modern AKIS is limited. Training is typically delivered as one-off sessions rather than embedded in advisory networks, constraining adoption and learning. Broader policy strategies for agricultural digitalisation are frequently developed in isolation from environmental, educational, and rural development policies, resulting in fragmentation. Furthermore, agroecology itself is inconsistently defined across stakeholder groups, reducing its visibility in markets and limiting institutional alignment.

Several policy frameworks already address elements of this agenda, including the Common Agricultural Policy (CAP), Horizon Europe, and the EU Data Act. Nonetheless, important gaps remain. Monitoring systems rarely provide evidence on agroecological outcomes, opportunities for farmer-led co-creation are limited, data governance structures remain contested, and investments in digital literacy and capacity building are insufficient. Addressing these shortcomings is crucial to ensure that digitalisation genuinely supports agroecological transitions in line with the EU Green Deal and Farm to Fork Strategy ambitions. Insights from the D4AgEcol project contribute directly to this task by identifying drivers, barriers, and risks of digital tools and by feeding evidence into EU and national policy roadmaps for agroecology.



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No.101060759. The project is co-funded by UK Research and Innovation (UKRI Reference No. 10037994). **Disclaimer:** The sole responsibility for any error or omissions lies with the editor. The content does not necessarily reflect the opinion of the European Commission. The European Commission is also not responsible for any use that may be made of the information contained herein.

Research Evidence & Policy Options



D4AgEcol

Research Summary & Findings

The D4AgEcol project mapped more than 100 digital tools and technologies across Europe and assessed 12 of them in-depth against agroecological principles, engaging farmers, advisors, policymakers, and technology providers through national workshops, an EU policy workshop, and Living Labs.

The mapped technologies strongly focus on efficiency improving, most of them (87 %) with a sensing or monitoring component. 64 % of the technologies focus on arable crops (Anastasou et al. 2024). While many tools focus on input use, our findings from digital tool scoping workshops with farmers and stakeholders show that 7 out of 10 assessed technologies face marginal or delayed profitability, creating adoption barriers (Maritan et al. 2025). Tools better aligned with agroecological needs, such as conservation planning apps, show higher potential.

Data justice emerged as a universal concern, with challenges in ownership, transparency, usability, and power asymmetries. Workshops emphasized the need for clear and equitable governance frameworks to unlock digitalisation for agroecological transitions (Landi et al. 2025).

Knowledge systems and co-creation proved decisive: Living Labs proved helpful to initiate the dialogue with farmers and stakeholders. Platforms such as NatApp can contribute to digital literacy, foster engagement, and support continuous adaptation of tools to local contexts. However, more experiences on effective design of interactive cooperations with farmers are needed to capture the co-creation potential.

“ Digitalisation can be useful, but the farmer is increasingly dependent on manufacturers. This is at least potentially a disadvantage.

Stakeholder comment, D4AgEcol survey results

“ Farmers adopt digital technologies not primarily for efficiency gains, but because they simplify operations and enable work under challenging conditions.

Martin Hirt, External Advisory Board Member D4AgEcol

“ Society's expectations of agriculture for ecosystem conservation are very high, but willingness to pay is still low.

Stakeholder comment, D4AgEcol survey results

Illustrative Examples



Efficient and labour-saving, but slowed by regulation, fragmentation, and skills gaps.



Reduced herbicide and labour, but hindered by cost and training



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No.101060759. The project is co-funded by UK Research and Innovation (UKRI Reference No. 10037994). **Disclaimer:** The sole responsibility for any error or omissions lies with the editor. The content does not necessarily reflect the opinion of the European Commission. The European Commission is also not responsible for any use that may be made of the information contained herein.

Research Evidence & Policy Options



Policy Challenges

- Digital tools remain efficiency-focused, with weak integration of biodiversity and social dimensions. Potential impact of many digital tools is not known yet.
- Poor usability, high costs, and limited co-creation restrict adoption, especially among small and medium-scale farms.
- Lack of clear and fair data governance limits trust, farmer autonomy and equitable value-sharing.
- Fragmented advisory systems and weak digital-agroecology education reduce awareness and practical use.
- Policy silos and inconsistent framing of agroecology undermine coherence, visibility, and support across value chains.

Policy Options

Align Digital Innovation with Agroecology

Ensure EU and national funding frameworks (e.g., CAP, Horizon Europe, Data Act standards) reward multi-dimensional agroecological outcomes rather than efficiency and overemphasis on efficiency.

Put Farmers at the Centre of Digital Design

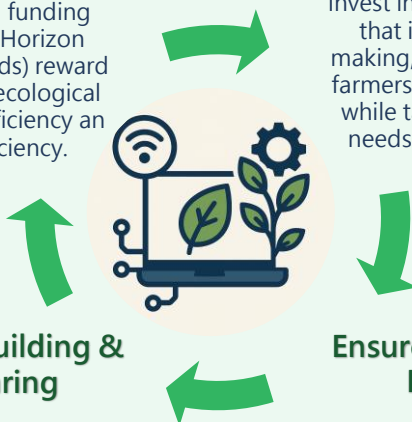
Invest in digital literacy and advisory systems that integrate agroecological decision-making, building regional hubs that connect farmers, advisors, and technology providers, while tailoring digitalisation to the specific needs of different countries, regions, and farming or forestry systems.

Enhance Capacity Building & Knowledge Sharing

Strengthen co-creation approaches, farmer-led innovation pilots, and targeted support and advisory services for small and medium farms to overcome adoption barriers.

Ensure Fair and Transparent Data Governance

Introduce enforceable farmer data rights, promote cooperative stewardship models (e.g., farmer-led data trusts), and link these to the European Agricultural Data Space.



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No.101060759. The project is co-funded by UK Research and Innovation (UKRI Reference No. 10037994). **Disclaimer:** The sole responsibility for any error or omissions lies with the editor. The content does not necessarily reflect the opinion of the European Commission. The European Commission is also not responsible for any use that may be made of the information contained herein.

Implementation & Call to Action



Target Audience

- **EU institutions (European Commission, DG AGRI, DG CONNECT, DG ENV):** regulatory alignment, funding calls, EU-wide standards.
- **Member States / CAP Managing Authorities:** adapt CAP Strategic Plans, integrate agroecological digitalisation in national advisory systems.
- **Regional Authorities / Advisory Services (AKIS, innovation hubs, Living Labs):** provide capacity building, facilitate co-creation, anchor peer learning.
- **Farmer cooperatives, data trusts, and innovation intermediaries:** ensure farmer-led governance and data stewardship.
- **Technology providers & research institutions:** co-design tools, ensure interoperability and ecological alignment.

Short Term

- Support Living Labs and participatory pilots where farmers, advisors, researchers and technology providers jointly test and refine digital tools.
- Pilot outcome-based subsidy schemes that use digital monitoring of agroecological indicators (e.g., biodiversity, soil health, circularity), ensuring that efficiency is not the only metric.
- The EU Data Act, together with the rollout of the Common European Agricultural Data Space (CEADS) and the European Digital Infrastructure Consortium (EDIC) for Agri-Food sectors, provides an opportunity to integrate data justice principles into agricultural digitalisation.
- CAP Strategic Plans can embed basic digital literacy and data skills into existing advisory services, eco-schemes, and knowledge exchange programs, promoting responsible use of digital tools among farmers, especially in rural areas.

Medium Term

- Develop and mainstream multidimensional evaluation frameworks (covering ecological, economic, and social outcomes) as a condition for CAP-supported digital tools.
- Establish regional digital-agriculture ecosystems through CAP-supported innovation platforms and the Agroecology Partnership, where farmers co-design tools with developers and advisors.
- Scale interoperable, farmer-led data stewardship models (e.g., cooperatives, data trusts) to ensure fair benefit-sharing and enable cross-border solutions.
- Expand serious games, peer-learning schemes, and knowledge hubs to support adaptive management, linking regional innovation platforms with AKIS structures.

Long Term

- Fully embed adaptive evaluation systems in CAP and Green Deal frameworks, ensuring continuous assessment of new technologies against agroecological outcomes.
- Institutionalise participatory design as a standard in digital agriculture R&I, with farmers recognised as equal partners in EU and national programmes.
- Maintain transparent, interoperable, and trusted data infrastructures across the European agri-food sector, linked to CEADS and supporting open science and innovation.
- Build a digitally competent European farming workforce by fully integrating agroecological digital skills into education, advisory systems, and lifelong learning programmes.

Further Reading

- 1) Anastasiou E, Stamatelopoulos P, Fountas S (2024) Mapping and Categorization of Existing and Emerging Technologies. Deliverable 1.1, D4AgEcol – Digitalisation for AgroEcology, Grant Agreement 101060759.
- 2) Maritan E, Gabriel A, Behrendt K, Spykman O, Lowenberg-DeBoer J, Gandorfer M, Meyer-Aurich A, Schwierz F (2025) Report on barriers and drivers of digitalisation adoption to enable agroecology. Deliverable 3.4, D4AgEcol – Digitalisation for AgroEcology, Grant Agreement 101060759.
- 3) Landi A et.al (2025) European Policy Roadmap. Deliverable 4.2 D4AgEcol, Grant Agreement 101060759.

