trans4num Policy Brief

Scaling Nature-Based Solutions for Circular and Resilient European Agriculture

30 November 2025

Deliverable D5.4

Funded by
the European Union

Project name	**Transformation for sustainable nutrient supply and management**
Project acronym	**trans4num**
Project ID	101081847
Project duration	December 2022 – November 2026
Project Coordinator	University of Hohenheim (UHOH)
Project website	https://trans4num.eu/
Work package	WP5
Work package leader	HIGHCLERE CONSULTING (HCC)
Deliverable number and title	D5.4 – 1 policy brief
Authors	Qirui Li, Andrea Knierim
Version	1
Dissemination level	PU

Table of Contents

List of tables

1. Preface

This deliverable (D5.4) presents the first policy brief developed within the trans4num project. It synthesises early insights from field experiments and stakeholder engagement in four European countries—Hungary, Denmark, the Netherlands, and the United Kingdom—and translates them into preliminary actionable messages for policymakers.

The brief draws on empirical findings reported in previous deliverables, particularly D2.3, the 2nd Report on NBS cases´ implementation and transdisciplinary evaluation (https://trans4num.eu/library/?type=DEL), to present how tested NBS innovations can contribute to restoring soil health, closing nutrient loops, and strengthening resilience while maintaining productivity. These practices directly support the overarching goals of trans4num, i.e., advancing circular nutrient management and enabling a just and sustainable transformation of agri-food systems.

The trans4num evidence demonstrates that NBS can deliver measurable environmental and economic benefits. However, their wider adoption is hindered by structural barriers, including fragmented governance, misaligned incentives, and regulatory uncertainty. Overcoming these barriers requires not only evidence-informed policymaking but also a deeper and more continuous policy dialogue that brings researchers, practitioners, decision-makers, and intermediary organisations into sustained interaction for aligning perspectives, exchanging experiential knowledge, and co-creating feasible transformation pathways toward more circular, resilient, and sustainable nutrient management systems.

The core text of the policy brief is included in Section 2 of this deliverable and outlines three interconnected policy priorities derived from the trans4num findings:

- Aligning incentives with ecosystem outcomes, by linking financial and regulatory support to tangible results such as soil carbon improvement and nutrient balance;
- Embedding adaptive governance and learning, through participatory monitoring, data-driven management, and collaborative/multi-actor nutrient councils[1]; and
- Integrating NBS across sectors and scales, to foster policy coherence between nutrient, water, biodiversity, and bioeconomy domains.

As the first in a series, this Policy Brief also introduces the themes that will be further explored in D5.6 in Month 44. Together, these briefs will build a cumulative understanding of how NBS can drive systemic change in nutrient management.

The intended audience for this Policy Brief can include EU-level institutions, particularly those shaping regulatory frameworks and funding mechanisms for soil, nutrient, and environmental management; competent authorities at Member State and regional levels, who adapt and implement these frameworks; and agricultural advisory organisations, which serve as intermediaries in policy development and uptake. By engaging these groups, the brief can contribute to an inclusive and forward-looking policy dialogue, supporting Europe's transition toward circular nutrient flows, resilient farming systems, and sustainable rural futures.

[1] Multi-actor nutrient councils are collaborative platforms that bring together stakeholders from agriculture, policy, research, advisory services, civil society, and industry to improve nutrient management through participatory governance and co-creation of solutions.

2. trans4num Policy Brief

Context: What NBS Matter for European Agriculture

European agriculture faces interconnected crises, such as climate stress, biodiversity loss, soil degradation, and nutrient pollution. The trans4num project attempts to explore how NBS can address these challenges by restoring ecological functions while maintaining productivity and rural viability.

Across Hungary, Denmark, the Netherlands and the United Kingdom, trans4num partners tested practical innovations (Table 1) for circular nutrient management, including crop diversification, compost use, bio-based fertilisers, and plant-based nutrient recycling. These approaches can reduce fertiliser dependence, enhance soil health, and create new value chains linking agriculture with the bioeconomy.

However, structural barriers, misaligned subsidies, fragmented governance, and regulatory uncertainty continue to limit adoption. As the EU debates the revision of the EC Nitrates Directive (including the proposed RENURE regulation), the Integrated Nutrient Management Action Plan (INMAP) policy initiative (under the Farm to Fork Strategy and Circular Economy Plan), and the post-2027 CAP (Directorate-General for Environment, 2025; European Commission., 2025; Joint Research Centre, 2023), there is significant potential for EU-level policymakers to make NBS a cornerstone of the necessary transition to a more sustainable agricultural sector. To achieve this, the following three key priorities are identified by trans4num**:**

1. Align incentives with ecosystem functions.
2. Embed adaptive governance and feedback learning.
3. Integrate NBS across sectors and policy levels.

Evidence from trans4num: Tested NBS Innovations

While implemented in different settings, the four NBS sites converge on a shared goal: reducing external inputs through ecological processes and circular resource flows.

Table 1. trans4num NBS innovations

NBS Sites	Practices	Tools	Outcomes	Barriers
Hungary – Szigetköz	Crop rotations (durum wheat, sorghum, soybean), no-till, winter cover crops, and biofertilisers.	Drone and sensor monitoring (NDVI, soil moisture, organic matter), digital DSS, and remote sensing.	Improved soil structure, enhanced soil biodiversity, higher nutrient-use efficiency, and reduced erosion.	Fragmented governance, an ageing workforce, and low value addition.
Denmark – Limfjord	Perennial grasses, grass–clover rotations, and nutrient recycling via biorefineries.	Remote sensing, nitrogen-flow modelling (Thers et al., 2025), farm-level nutrient visualisation tools, and a regulatory sandbox.	Lower nitrogen leaching, bio-based fertiliser products, and emerging circular biomass value chains.	Uncertain CAP support, weak biomass markets, and established local practices that limit uptake of new approaches.

United Kingdom – Harpenden & Devon	Harpenden: long-term compost trials, reduced tillage, and crop diversification (Li et al., 2023); Devon: Thallo P-fertiliser trial.	Harpenden: long-term research platforms, soil biodiversity and carbon tracking; Devon: block field trials and nutrient-density testing.	Higher nutrient efficiency, increased soil carbon, reduced reliance on mineral fertilisers, and a circular P pathway.	Market acceptance, regulatory approval, economic viability, and weather variability.
Netherlands – Ebelsheerd & Kollumerwaard	Lucerne (Alfalfa) and grass–clover pellets, green manures, cover crops, and plant-based nutrient strategies.	NDICEA model (Van Der Burgt et al., 2006), scenario modelling for manure-free systems, and crop-quality monitoring.	Reduced dependence on manure and synthetic fertilisers, improved soil fertility, and market potential for vegan-labelled crops.	Restrictive nutrient regulations, limited advisory support, and market uncertainty.

Policy Priorities and Recommendations

The following priorities represent three mutually reinforcing areas of action identified through evidence review and stakeholder feedback.

Align Incentives with Ecosystem Functions

To enhance the adoption of NBS, it is essential to orient CAP eco-schemes and payments toward outcome-based indicators, such as soil carbon, nutrient balance, and biodiversity. Circular nutrient sources, including compost, bio-based, and plant-based fertilisers, should be explicitly recognised with clear standards and monitoring procedures to ensure their effective integration. Additionally, introducing Payment for Ecosystem Services (PES) and green finance instruments that reward ecosystem restoration can provide strong economic incentives for farmers. Together, these measures can reduce dependency on synthetic fertilisers, improve nutrient self-sufficiency, and strengthen rural value chains.

Embed Adaptive Governance and Feedback Learning

Adaptive governance mechanisms enable nutrient management policies to evolve with changing conditions and emerging evidence. Denmark offers a strong example: recent studies show how the combination of national nitrogen regulations with analytical tools, such as the N-footprint approach (Vos et al., 2025) and the CIRKULÆR systems model (Thers et al., 2025), helps test scenarios, anticipate trade-offs, and iteratively adjust measures based on science-based insights. Establishing multi-actor nutrient councils can further institutionalise stakeholder engagement in interpreting evidence and co-shaping nutrient strategies. Strengthening the Farm Sustainability Tool for Nutrients (FaST, https://fastplatform.eu/whatisfast) as a participatory data platform would help link farm-level information with policy design, enhancing transparency, trust, and the responsiveness of nutrient governance systems.

Integrate NBS Across Sectors and Policy Levels

For NBS to achieve systemic impact, it is necessary to coordinate nutrient, water, and biodiversity policies to prevent conflicting objectives and promote coherence. Supporting

regional bioeconomy hubs that connect agriculture with renewable energy production and biorefineries can create opportunities to valorise agricultural residues and biomass. In parallel, developing shared data infrastructures that integrate experimental results and experiential learning with CAP performance reporting can strengthen evidence-based policy implementation. By combining these measures, European agricultural systems can achieve more coherent policy outcomes and efficient use of resources across sectors and scales.

Managing Trade-offs

NBS generate multiple benefits but also involve trade-offs that need to be carefully managed. Ecologically, there is a need to balance carbon storage with the maintenance of habitat diversity (Chen et al., 2018; Johnson et al., 2014). Economically, the adoption of compost and bio-based fertilisers can entail higher short-term costs for farmers (Medici et al., 2025; Moshkin et al., 2023). Socially, risk aversion and generational barriers may limit willingness to adopt new practices (Dibbern et al., 2024; Long et al., 2016). Policy design should therefore focus on managing these tensions by promoting transparent communication, participatory planning, and equitable mechanisms for sharing the benefits of NBS.

Implications and Next Steps

Evidence from trans4num shows that NBS can generate measurable environmental and economic benefits when supported by coherent governance and well-aligned incentives. To unlock this potential, EU and national strategies may explicitly recognise circular nutrient sources and promote regenerative, circular farming practices across relevant instruments and funding streams. Strengthening platforms, research initiatives, and knowledge hubs that collectively support knowledge gathering, data sharing, policy guidance, and collaboration on NBS for agriculture, embedded within broader environmental, biodiversity, and climate strategies, could enhance coherence and uptake. Piloting NBS and INMAP in high-pressure regions such as the Netherlands and Denmark can further demonstrate practical pathways for wider adoption. Embedding NBS in agricultural policy offers a realistic route to achieving Europe's climate, biodiversity, and food-security goals, turning local innovations into mainstream practice.

3. Conclusion and Next Steps

This first policy brief translates the empirical findings from the trans4num NBS sites into insights for European policy. Building on field-level experimentation and multi-actor engagement across Hungary, Denmark, the Netherlands, and the United Kingdom, it highlights how NBS can contribute to more circular and resilient nutrient management systems while also identifying the structural and institutional barriers that still limit their wider adoption.

A key conclusion is that NBS can deliver measurable environmental and economic benefits, improving soil health, nutrient efficiency, and carbon retention, yet their success depends on enabling conditions that go beyond the farm scale. These include coherent and supportive policy frameworks, viable market incentives, effective advisory systems, and mechanisms that foster trust, learning, and collaboration among diverse actors. Technical effectiveness alone is not sufficient, so the transformation toward circular nutrient management requires systemic alignment across governance levels, sectors, and instruments.

Several cross-cutting insights emerge from the evidence synthesised in this brief:

- Circularity as a shared goal: Each NBS site tests different yet complementary pathways, i.e., biofertiliser use in Hungary, perennial rotations and biorefinery integration in Denmark, compost-based fertilisation in the UK, and plant-based nutrient strategies in the Netherlands, with all contributing to closing nutrient loops.
- Persistent policy and market tensions: Misaligned incentives, regulatory uncertainty, and fragmented governance frameworks constrain innovation and limit farmers' willingness to adopt NBS.
- The role of transdisciplinary learning: Joint reflection among farmers, advisors, researchers, and policymakers has proven essential for identifying context-sensitive solutions and ensuring that local practices inform policy design.

The policy brief underscores that enabling a just and sustainable nutrient transition in Europe will require aligning policy instruments with measurable ecosystem outcomes and circular economy principles. Thus, next steps for trans4num may include:

- Deepening cross-country synthesis: Consolidate evidence from all NBS sites to refine policy recommendations, highlighting the environmental, economic, and social performance of NBS in diverse contexts.
- Linking research outputs to decision support: Provide a clear overview of the DSS tool, its purpose, main functions, and practical use, ensuring that policymakers and practitioners can apply it for evidence-based planning and scenario analysis.
- Translating findings into actionable pathways: Build on the assessments and recommendations from D5.4 policy brief (Month 36) and D4.3 Map on value-chain level impacts of NBS across scenarios (Month 45) to guide the design of integrated governance, financing, and policy measures that support circular nutrient management and regenerative practices.
- Strengthening policy engagement and dissemination: Expand outreach through thematic briefs, stakeholder dialogues, and targeted communication materials to ensure that insights from NBS sites and the DSS tool inform both national and EU-level decision-making.
- Preparing the second policy brief: Combine ongoing evaluation results and foresight analyses to deliver a consolidated overview of NBS performance, transformation pathways, and recommended policy interventions, supporting coherent and scalable adoption across Europe.

4. References

Chen, S., Wang, W., Xu, W., Wang, Yang, Wan, H., Chen, D., Tang, Z., Tang, X., Zhou, G., Xie, Z., Zhou, D., Shangguan, Z., Huang, J., He, J.-S., Wang, Yanfen, Sheng, J., Tang, L., Li, X., Dong, M., Wu, Y., Wang, Q., Wang, Z., Wu, J., Chapin, F.S., Bai, Y., 2018. Plant diversity enhances productivity and soil carbon storage. Proc. Natl. Acad. Sci. U.S.A. 115, 4027–4032. https://doi.org/10.1073/pnas.1700298114

Dibbern, T., Romani, L.A.S., Massruhá, S.M.F.S., 2024. Main drivers and barriers to the adoption of Digital Agriculture technologies. Smart Agricultural Technology 8, 100459. https://doi.org/10.1016/j.atech.2024.100459

Directorate-General for Environment, 2025. Commission welcomes RENURE agreement in Nitrates Committee.

European Commission, 2025. The CAP post-2027 in the next EU budget. Common agricultural policy overview.

Joint Research Centre., 2023. Knowledge for Integrated Nutrient Management Action Plan (INMAP). Publications Office of the European Union, Luxembourg. https://publications.jrc.ec.europa.eu/repository/handle/JRC129059

Johnson, J.A., Runge, C.F., Senauer, B., Foley, J., Polasky, S., 2014. Global agriculture and carbon trade-offs. Proc. Natl. Acad. Sci. U.S.A. 111, 12342–12347. https://doi.org/10.1073/pnas.1412835111

Li, X., Storkey, J., Mead, A., Shield, I., Clark, I., Ostler, R., Roberts, B., Dobermann, A., 2023. A new Rothamsted long-term field experiment for the twenty-first century: principles and practice. Agron. Sustain. Dev. 43, 60. https://doi.org/10.1007/s13593-023-00914-8

Long, T.B., Blok, V., Coninx, I., 2016. Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy. Journal of Cleaner Production 112, 9–21. https://doi.org/10.1016/j.jclepro.2015.06.044

Medici, M., Calvia, M., Greggio, N., Buscaroli, A., Marazza, D., Canavari, M., 2025. How do farmers value organic fertilisers? An exploratory study on conventional and innovative products. Farming System 3, 100156. https://doi.org/10.1016/j.farsys.2025.100156

Moshkin, E., Garmendia Lemus, S., Bamelis, L., Buysse, J., 2023. Assessment of willingness-to-pay for bio-based fertilisers among farmers and agricultural advisors in the EU. Journal of Cleaner Production 414, 137548. https://doi.org/10.1016/j.jclepro.2023.137548

Thers, H., Uldall-Jessen, L., Sahlholdt, A.M., Odgaard, M.V., Madsen, A.K.L., Dalgaard, T., Kristensen, T., Miranda-Vélez, J.F., 2025. The CIRKULÆR model – A national and regional static flow model of agricultural production, environmental and climatic impacts. Agricultural Systems 229, 104415. https://doi.org/10.1016/j.agsy.2025.104415

Van Der Burgt, G.J.H.M., Oomen, G.J.M., Habets, A.S.J., Rossing, W.A.H., 2006. The NDICEA model, a tool to improve nitrogen use efficiency in cropping systems. Nutr Cycl Agroecosyst 74, 275–294. https://doi.org/10.1007/s10705-006-9004-3

Vos, J.L., Leach, A.M., Galloway, J.N., Dalgaard, T., Graversgaard, M., 2025. The Danish nitrogen footprint: balancing regulation with individual environmental responsibility. Environ. Res. Lett. 20, 054026. https://doi.org/10.1088/1748-9326/adc0b2