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Practice Abstracts for farmers, 2nd batch

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1. Introduction

1.1 Purpose of this deliverable

The purpose of the deliverable D5.7 is to provide the second batch of 15 practice abstracts tailored for farmers and agricultural advisors. These abstracts aim to:

- Translate project results and insights into accessible, practical knowledge that supports the implementation of nature-based solutions on the ground.
- Facilitate knowledge transfer by summarising innovative practices, tested solutions and field-level experiences in a concise, easy-to-read format.
- Support Horizon Europe's wider goals of boosting sustainability, resilience and biodiversity in farming through dissemination of results that are usable by practitioners.
- Fulfil contractual obligations under the trans4num project by submitting practice abstracts to DG AGRI in the official EIP-AGRI common format, aligned with the EU CAP Network requirements.
- Lay the foundation for wider dissemination via publication across key platforms including trans4num website, Zenodo and EU FARMBOOK.

Ultimately, this deliverable contributes to bridging the gap between research and practice, ensuring that the benefits of NBS innovations reach farmers in a usable and impactful way.

1.2 Role of Practice Abstracts (PAs) in trans4num

Practice Abstracts (PAs) in trans4num play a central role in translating research and innovation into practical knowledge for farmers and advisors who are the main users of nature-based solutions. As a contractual obligation under Horizon Europe this PAs ensure that the project meets its multi-actor requirements for knowledge transfer and practical impact.

Specifically, the PAs aim to:

- Communicate real, actionable solutions
- Facilitate uptake of NBS by farmers
- Serve as foundation for further dissemination
- Strengthen the visibility and usability of project outcomes
- trans4num will deliver (over) 30 PAs in two batches:
    - 17 PAs in D5.3 (Month 33, August 2025)
    - 15 PAs in D5.7 (Month 44, July 2026)

2. Methodology

2.1 Overview of the preparation and coordination process

For this deliverable, the preparation process was more streamlined, as project partners had already gained experience in developing Practice Abstracts during the first submission. Nevertheless, WP5 team followed the same structured approach to ensure consistency and quality across all abstracts. This included:

- An internal survey to identify Practice Abstract topics and assign lead authors;
- Monthly "drop-in" meetings to address questions and provide support throughout the drafting process;
- Standardised templates provided to each author and partner to ensure a consistent structure and format.

2.2 Timeline and workflow

To support the preparation of Deliverable 5.7, all European and Chinese project partners were invited to propose Practice Abstract topics based on the work carried out within the trans4num project. For this second batch of 15 Practice Abstracts, a slightly adapted approach was adopted to facilitate partners' engagement and reduce the overall workload.

Following an internal survey, which received a limited number of responses, and subsequent discussions between the project coordination team and WP5, it was agreed to make use of artificial intelligence to generate initial drafts based on project deliverables, technical reports, publications, and news articles produced by the consortium. These draft Practice Abstracts were then shared with the respective partners for review, validation, and further refinement to ensure their technical accuracy and practical relevance. Once finalised, the abstracts were transferred into the trans4num factsheet template developed in Canva.

The trans4num factsheet represents an enhanced version of the traditional Practice Abstract. While maintaining the same core structure (explaining the why, what, and how of each innovation) it provides additional practical information and a more visually engaging format through the inclusion of photographs, diagrams, key results, and practical recommendations. This approach aims to improve readability and facilitate the dissemination and uptake of project results by farmers, advisors, policymakers, and other relevant stakeholders.

The drafting process commenced in March 2026, providing partners with a three-month period to prepare new Practice Abstracts or review and refine the AI-generated drafts.

The same approach was applied to the trans4num China consortium, including an invitation to propose topics through an internal survey, the preparation of AI-generated Practice Abstracts based on project outputs, and several follow-up reminders requesting review and validation. In these communications, partners were informed that, should no feedback be received within the specified timeframe, the drafts would be considered approved for publication in their current form. Despite these efforts, no feedback or revisions were received from the trans4num China partners during the given time. Consequently, the Practice Abstracts included in this deliverable are based on information extracted from the available project deliverables and other project outputs.

3. Overview of the Practice Abstracts

Deliverable 5.7 includes 15 new Practice Abstracts, increasing the total number of Practice Abstracts produced by the trans4num project to 32. These outputs have been submitted to the EIP-AGRI platform and will be disseminated through the project's communication activities to support the uptake of project results by farmers, advisors, researchers, and other relevant stakeholders.

Table 1 provides an overview of the 17 Practice Abstracts submitted in M33 (July 2025), including their leading partner and DOIs, while ***Table 2*** presents the 15 Practice Abstracts submitted as part of Deliverable 5.7.

The first batch of trans4num practice abstracts reflects a well-balanced and diverse range of themes that are closely aligned with the project's overarching Nature-Based Solutions (NBS) objectives. The topics cover a variety of agroecological contexts, farming systems, and intervention types, from plant-based fertilization and regenerative crop rotations to remote sensing, pest management, and green biorefining. This diversity demonstrates the project's commitment to exploring both technological and nature-based innovations across scales.

The second batch of trans4num practice abstracts builds on the project's technical results by placing greater emphasis on the practical implementation, monitoring, scaling, and uptake of Nature-based Solutions (NBS). While continuing to showcase innovative nutrient management practices across the project's European and Chinese demonstration sites, this collection extends beyond individual technologies to address the enabling conditions required for successful adoption, including advisory systems, Agricultural Knowledge and Innovation Systems (AKIS), decision-support tools, monitoring approaches, and stakeholder collaboration.

The Practice Abstracts present a diverse portfolio of solutions ranging from circular nutrient management, organic fertiliser substitution, conservation agriculture, and crop residue valorisation to soil health monitoring, educational demonstration tools, and recycled bio-based fertilisers. They demonstrate how NBS may contribute to improving soil fertility, nutrient-use efficiency, climate resilience, resource circularity, and farm profitability while reducing dependence on synthetic inputs and strengthening ecosystem services.

A cross-cutting message emerging from this second batch is that successful implementation depends not only on the technical performance of individual practices, but also on effective knowledge exchange, long-term monitoring, strong advisory services, farmer engagement, and supportive policy frameworks. Several PAs therefore focus on tools and approaches that help farmers and advisors make better-informed decisions, including soil and plant monitoring, CO_2 emission measurements, landscape-scale decision-support systems, and experiential learning environments designed to make complex soil processes visible and understandable.

Table 1 Overview of the first batch of practice abstracts

Partner	Title	DOI
SPNA	AgriFuture: Innovating Crop Rotations & Soil Health on Clay Soils	https://doi.org/10.5281/zenodo.15647060
SPNA	AgriFuture: Innovative Crop Strategies for Seed Potato Cultivation	https://doi.org/10.5281/zenodo.15647041
SPNA	Green Fertilizers: Lucerne and Clover Pellets for Winter Wheat	https://doi.org/10.5281/zenodo.15647033
SPNA	Plant-Based Fertilizer and Natural Crop Protection in Seed Potatoes	https://doi.org/10.5281/zenodo.15647027
WU	Cut-and-Carry Green Manure: Opportunities for Plant-Based Nutrient Management in Potato Systems	https://doi.org/10.5281/zenodo.15647020
SPNA	Planty Organic: Long-Term Crop Rotation with Plant-Based Nutrition	https://doi.org/10.5281/zenodo.15647108
AU	Grass-Based Cropping Systems: Transforming the Danish Agricultural Landscape	https://doi.org/10.5281/zenodo.15647090
CO	Regional Scale Satellite Monitoring	https://doi.org/10.5281/zenodo.15647085
KFS	From Grass to Value: Refining Green Biomass for Protein and Nutrients	https://doi.org/10.5281/zenodo.15647082
KFS	Circular Systems in Action: Cascade Utilization and Industrial Symbiosis	https://doi.org/10.5281/zenodo.15647070
RRes	Nature-Based Solutions for Insect Pest Management	https://doi.org/10.5281/zenodo.15853864
RRes	Soil Carbon Stewardship and Nature-Based Solutions: Managing Soil Organic Carbon	https://doi.org/10.5281/zenodo.15853852
SZE	Monitoring Nature: Remote Sensing as a Key Enabler of Nature-Based Solutions	https://doi.org/10.5281/zenodo.15647014
SZE	Look Into the Soil to Understand the Benefits of NBS for Soil	https://doi.org/10.5281/zenodo.15646995
SZE	Fostering Population Growth of Kestrel (Falco Tinnunculus) in Agricultural Areas	https://doi.org/10.5281/zenodo.15646985
P4all	Cultivating Innovation – trans4num Hackathon Highlights	https://doi.org/10.5281/zenodo.15647062
UHOH	Small Actions in Light of Transformation	https://doi.org/10.5281/zenodo.15646956

Table 2 Overview of the second batch of practice abstracts

Partner	Title	Location	DOI
FiBL, CO	trans4num Decision support tool	Denmark	https://doi.org/10.5281/zenodo.21264799
UHOH	Scaling Nature-Based Solutions Through Strong Networks	Europe	https://doi.org/10.5281/zenodo.21263575
RRES	Benefits of compost and cover crops for soil health and yield	United Kingdom	https://doi.org/10.5281/zenodo.21263671
RRES	From animal waste to plant nutrition	United Kingdom	https://doi.org/10.5281/zenodo.21264805
PKE	Experiential and Mobile tools for climate -resilient agriculture and soil regeneration	Hungary	https://doi.org/10.5281/zenodo.21264839
PKE	Soil profile display	Hungary	https://doi.org/10.5281/zenodo.21264889
SZE	Soil CO^2 emission monitoring	Hungary	https://doi.org/10.5281/zenodo.21264869
SZE	Monitoring-supported decision making for effective NBS	Hungary	https://doi.org/10.5281/zenodo.21264878
CAAS	No-tillage soybean systems for improved soil moisture and yield stability	China	https://doi.org/10.5281/zenodo.21264895
SWU	Organic fertiliser substitution to improve soil carbon and nutrient efficiency	China	https://doi.org/10.5281/zenodo.21264858
HAAS	Straw-based crop-mushroom systems for circular nutrient use and soil restoration	China	https://doi.org/10.5281/zenodo.21264902
FiBL	Using modelling tools to support better farming and policy decisions	Europe	https://doi.org/10.5281/zenodo.21264825
SZE, PKE	HU: Integrating NBS for sustainable nutrient management	Hungary	https://doi.org/10.5281/zenodo.21264928
SPNA, WU	NL: Integrating NBS for sustainable nutrient management	Netherlands	https://doi.org/10.5281/zenodo.21264844
RRES	UK: Integrating NBS for sustainable nutrient management	United Kingdom	https://doi.org/10.5281/zenodo.21264913

4. Dissemination

The 15 new trans4num factsheets will be disseminated as downloadable PDF files through a range of strategic platforms to maximise their accessibility, visibility, and long-term availability. Following their submission to the EIP-AGRI database, the factsheets will be published in the Library section of the trans4num project website under the dedicated Practice Abstracts subsection.

To enhance discoverability, accessibility, and citation, all factsheets have been uploaded to Zenodo, where each has been assigned a unique Digital Object Identifier (DOI).In addition, the complete collection of Practice Abstracts will be available through the trans4num project page on EU-FarmBook, contributing to the European knowledge base for farmers, advisors, researchers, and other agricultural practitioners. The factsheets will also be shared via OPPLA, furt

To
communication campaign through the project's LinkedIn channel, featuring each Practice Abstract individually. Partners will also be encouraged to share the factsheets through their own institutional communication channels and professional networks, helping to maximise visibility, knowledge exchange, and the adoption of the project's results by relevant stakeholder groups.

5. Annexes

5.1 trans4num practice abstracts

PA trans4num Decision support tool

PA Scaling nature-based solutions through strong networks

PA Benefits of compost and cover crops for soil health and yield

PA From animal waste to plant nutrition

PA Experiential and mobile tools for climate -resilient agriculture and soil regeneration

PA Soil profile display

PA Soil CO2 emission monitoring

PA Monitoring-supported decision making for effective NBS

PA No-tillage soybean systems for improved soil moisture and yield stability

PA Organic fertiliser substitution to improve soil carbon and nutrient efficiency

PA Straw-based crop-mushroom systems for circular nutrient use and soil restoration

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5.2 EIP-AGRI generated template

trans4num DECISION SUPPORT TOOL

Summary

The trans4num Decision Support Tool (DST) helps bridge the gap between farm-level nutrient management and its broader environmental impacts. By linking field-level actions to landscape-scale outcomes, it supports farmers, advisors, and policymakers in planning and optimising nature-based solutions, visualising trade-offs, and collaboratively finding efficient, regionally adapted strategies for sustainable agriculture.

The need

The need for the trans4num Decision Support Tool (DST) primarily stems from a critical mismatch in scale between agricultural decision-making and its environmental impacts. While decisions regarding nutrient management are usually made at the individual farm or field level, the resulting environmental consequences, such as nitrogen leaching, water pollution, biodiversity loss, and soil degradation, manifest at a much broader landscape scale.

Because of this disconnection, a clear need was identified for a tool that could address the following challenges:

- Bridging the gap between field actions and landscape outcomes
- Visualizing trade-offs between multiple environmental targets and agronomic productivity on various spatial scales
- Planning and operationalizing Nature-Based Solutions (NBS) at landscape level
- Fostering active collaboration both between farmers, advisors, policy makers and the broader bioindustry



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The benefits

Benefits for farmers and farmer associations

- **Connecting actions to outcomes**: Shows how field-level management choices impact broader landscape outcomes, making the green transition more tangible
- **Identifying new value chains**: Alternative scenarios can reveal economic opportunities. For example, perennial grass or catch crops that reduce nutrient losses while opening access to green biorefining markets
- **Flexible, realistic scenarios**: Evaluates full crop rotations rather than single-year crops, with recommendations kept within practical limits rather than unrealistic farm-type overhauls
- **Collaborative problem-solving**: Empowers cooperatives and farmer clusters to jointly find efficient, economically viable solutions across a shared landscape

Benefits for agricultural advisors

- **Facilitating strategic dialogue**: Supports communication between farmers, policymakers, and water managers to collaboratively plan and implement nature-based solutions
- **Visualising trade-offs**: Helps demonstrate the balance between environmental targets and regional economic returns, making efficient solutions easier to identify
- **Enhancing the advisory role**: Advisors act as trusted facilitators, translating technical outputs into practical language, which has been shown to improve farmer understanding and uptake

Benefits for regional planners and policymakers

- **Supporting collaborative policy development**: Provides a shared platform for planners, policymakers, and farmers to jointly explore and co-design solutions in multi-stakeholder settings
- **Assessing feasibility of policy options:** Helps evaluate which interventions are realistic under actual farming conditions, improving the practicality of proposed measures

trans4num DECISION SUPPORT TOOL

trans4num solution

How the DST works: technical background

The DST is a spatially explicit, data-driven optimisation tool that captures both the impact of NBS implementation under geographically varying conditions.

- Optimisation engine: Uses mixed-integer programming to evaluate and allocate alternative crop rotations and management strategies across all fields within a defined landscape
- Transition matrices: Lookup tables that quantify the effects of shifting from one management practice to another — such as nitrogen leaching, yield, and economic return — based on local soil types. These must be developed case-specifically from field experiments, expert knowledge, or regionally adapted process-based models
- Geographic variability: Spatial variability is captured at field level using crop code and soil type, allowing the model to reflect how NbS effectiveness varies across the landscape — for example, differences in nitrogen retention between fields
- Software architecture: A React-based frontend and Python backend connected via a REST API. The model engine processes multiple data formats, including tabular data (CSV, JSON) and spatial files (GeoTIFF, GeoJSON, Shapefile)

How the DST works: user experience

The DST does not prescribe decisions or predict exact outcomes. Instead, it starts from a desired effect and visualises possible ways to achieve it — serving as a basis for discussion and collaborative solution-finding among diverse stakeholders.

- Two-step input process: Users first select a regional optimisation goal, then apply constraints to limit options and ensure realistic scenarios
- Exploring trade-offs: The model identifies the most efficient spatial allocation to meet defined goals. If a goal is too ambitious or constraints too restrictive, the model signals this — providing valuable insight into what is realistically achievable
- Visual outputs: Results include spatial maps comparing the status quo with the optimised alternative field by field, pie charts showing crop shares before and after optimisation, and radar views for comparing economic and environmental performance across model runs. The nitrogen balance of the whole region is also reported.



What were the challenges / limitations in the implementation process?

- High complexity and need for facilitation: as the tool targets landscape settings, its intended use is primarily in facilitated workshop settings rather than as a standalone tool for individual farmers.
- Case-specific adaptation and data requirements: Applying the DST to new regions requires substantial local data input, with transition matrices in particular often proving difficult to obtain.



What kind of resources do you need to implement the proposed solution?

- Spatially explicit agricultural data
- Defined goals for a region
- Defined effect of an NBS that varies geographically due to spatially varying data.
- Data describing effects of an introduced NBS
- A trusted facilitator (modeller, researcher or advisor)

trans4num DECISION SUPPORT TOOL

More information

Transferability of the DST

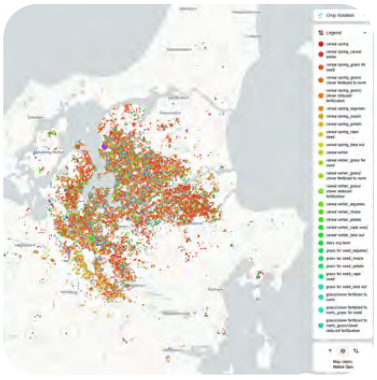
- The DST was developed for the Limfjord, Denmark, but its structure is transferable to other regions. Adaptation is required, including a clear regional optimisation target, appropriate constraints, and relevant data inputs such as transition matrices and geospatial datasets.

How the DST was developed

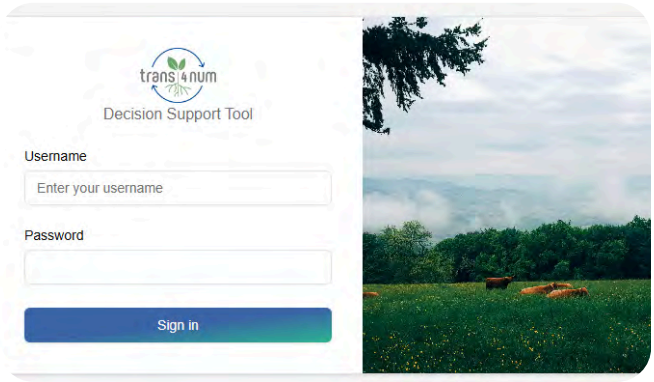
- Development was collaborative and iterative, bringing together researchers across agronomy, soil sciences, spatial data science, and social sciences. Through this process, a key gap in existing tools was identified - the need to link field-level actions to landscape-scale outcomes.
- Co-design: Transdisciplinary workshops with farmers, advisors and regional planners in Denmark shaped key refinements, including evaluation of full crop rotations and constraints to prevent unrealistic farm-type changes.
- Iterative testing through DST workshops in Hungary, the Netherlands, and the UK demonstrated the tool's value in facilitating discussion across diverse landscape settings and governance structures.

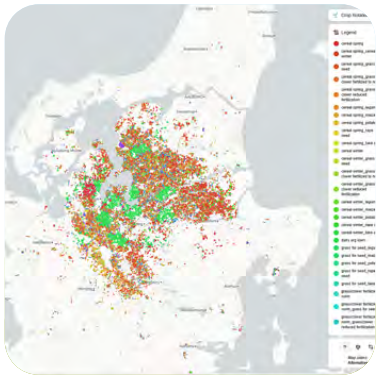
- Explore the DST
- Find more Practice Abstracts: https://trans4num.eu/library/?type=ABS













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SCALING NATURE-BASED SOLUTIONS THROUGH STRONG NETWORKS

Summary

Successful nature-based solutions (NBS) depend not only on the technologies being developed, but also on the people and organisations that support them. The trans4num project found that innovations are more likely to move beyond pilot projects when farmers, advisors, researchers, businesses, and policymakers work together over time. Strong Agricultural Knowledge and Innovation Systems (AKIS), stable funding, and continuous knowledge exchange help adapt innovations to local conditions and increase their long-term uptake. In contrast, fragmented networks, missing actors, and short-term support can limit the wider adoption of promising solutions.

The need

Promising innovations on nature-based solutions (NBS) remain in early innovation phases because they are not well supported by strong networks of farmers, advisors, businesses, and policymakers. Across countries, weak coordination, missing actors, and fragmented funding challenge innovations stability and development for turning them into everyday farming practices.

The benefits

Well-functioning AKIS enables innovation reflection through different actors with diverse views which supports farmers access to practical knowledge, risk reduction, and adoption of new practices. Strong cooperation between actors improves the chances that innovations can be applied to local conditions, economically viable, and supported by policy and markets.





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SCALING NATURE-BASED SOLUTIONS THROUGH STRONG NETWORKS

trans4num findings

trans4num shows that successful solutions depend on how well actors work together over time, not just on the technology itself. Different country examples highlight this:

- Denmark: Strong cooperation over decades between farmers, advisors, researchers, and industry supports innovation (e.g. biorefineries), backed by stable funding and clear roles
- Netherlands: Farmer-led networks in cooperation with research drive innovation, but lack of formal support and funding challenged development stability
- Hungary: Advisory systems are more top-down, with limited farmer involvement and uneven access to knowledge
- United Kingdom: Product innovations driven by companies and researchers struggled to be applied outside trial sites.

This shows that balanced partnerships and good coordination are essential for success. Moreover, trans4num research shows that:

- High interest by farmers when involved early - Innovations on Nature-based solutions (NBS) were likely to be tested when farmers participated from the start (co-design, testing, feedback) and shared the innovation in their networks.
- Advisors as intermediaries - Trusted advisors help integrating research into practice, as farm-ready actions, and private sector advisors feed back new innovations to their company.
- Strong networks over time enable moving beyond pilot sites - When an innovation was well supported by the AKIS (e.g. Denmark), innovations moved from trials to wider adoption through coordinated farmer–advisor–industry collaboration.
- Network diversity alone is not enough - Diverse networks can have weaknesses when actor number and linkages are sparse (e.g. Hungary) or when informal networks (e.g. Netherlands) dependent on a few motivated actors.
- Missing broader actors involvement - Lack of involvement of additional actors (e.g. actors apart from core innovation group and research in UK, or private sector in NL) led to gaps between innovation and real-world application.
- Stable funding and coordination are essential - Long-term success depended on consistent funding, advisory support, and broadening the innovation in various actor groups.



What were the challenges / limitations in the implementation process?

- Innovations potentially remain (longer) in a trial phase if key actors (e.g. farmers or advisors) are missing
- Weak coordination between policy, research, and practice slows innovation stabilisation
- Short-term or fragmented funding challenges long-term impact
- Limited communication between stakeholders reduces trust and uptake



What kind of resources do you need to implement the proposed solution?

- Strong advisory systems: trusted advisors linking research farmers and businesses
- Inclusive networks: a diversity of actors that are densely linked
- Stable funding: long-term financial and infrastructural (e.g. trial sites) support
- Knowledge exchange: regular interaction within and across actor groups, demonstration farms, and peer learning

SCALING NATURE-BASED SOLUTIONS THROUGH STRONG NETWORKS

AKIS is a concept rather than a formal structure, so it is not the AKIS itself that is convened, coordinated, or directed. Rather, responsibility lies with the actors and intermediary arrangements that connect the relevant stakeholders and support innovation processes. These intermediaries do not necessarily need to be highly institutionalised. The Danish case shows the value of a relatively stable and trusted regional innovation intermediary with a broad mandate across sectors, but the Dutch case demonstrates that less formalised, network-based forms of coordination can also play an important role. In both cases, what matters is the ability to bring together farmers, advisors, researchers, value-chain actors, public authorities, and civil society, and to facilitate knowledge exchange and innovation development in context-specific ways.

For the Danish case in particular, the recommendation would be that innovation should be supported by a trusted regional innovation intermediary or multi-actor platform that can engage actors beyond agriculture, including processing industries, energy companies, municipalities, and relevant ministries. However, this should not be understood as a one-size-fits-all model: the appropriate form of coordination depends on the stage of the innovation process, the type of innovation, and the (institutional) context.

- Visit trans4num website: https://trans4num.eu/en/
- NBS sites: https://trans4num.eu/en/sites/
- Library: https://trans4num.eu/en/library-all/









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BENEFITS OF COMPOST AND COVER CROPS FOR SOIL HEALTH AND YIELD

Summary

The benefits for crop yields and soil health of adding green compost to fields and growing cover crops depends on how the soil is cultivated and the local soil texture. The amount of clay in the soil determines the availability of nutrients released and how much additional soil organic carbon is retained.

The need

The rising cost of synthetic fertilisers and their negative impact on the environment through greenhouse gas emissions and leaching has focussed attention on organic amendments as a possible nature-based solution for providing crops with nutrients and improving soil health. Sources of organic material include green municipal waste ('compost') and /or growing cover crops over winter but the benefits for crop yield and soil health will depend on other properties of the cropping system and the local environment.

If the benefits of organic substitution for synthetic fertilisers are to be fully realised, farmers and advisors need evidence for the expected response of crops and soils in their local context. This can help inform adaptation of management in a way that improves efficiencies of input use and builds resilience to extreme weather and climate change through healthier soils. Because these benefits can accrue over many years, we also need evidence for the long-term benefits of organic amendments to manage expectations in the short term and underpin long term decision making.

Finally, the benefits of organic amendments and cover crops will depend on how they are combined with other nature based solutions, including crop rotations and reduced tillage. This 'systems level' understanding will further inform locally optimised decision making.



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The benefits

Adding compost to the soil and growing cover crops (especially if they are nitrogen fixing legumes) provides a source of nutrients, including nitrogen and phosphourus, to following crops. This additional nutrition has the potential to reduce the need for applications of synthetic fertiliser, reducing costs and the environmental impacts of its manufacture and use.

Compost and cover crops are also a source of additional organic carbon. The loss of soil organic carbon over recent decades as a result of the reliance on inorganic fertilisers has been identified as a potential threat to the sustainability of crop production. Specifically, the degredation of soil structure as a result of the loss of organic carbon has compromised the hydraulic properties of soils, exacerbating the negative impacts of floods and droughts. Cover crops can also benefit the hydraulic conductivity of soils by creating connected macro pores through root growth.

Finally, the use of compost and cover crops has the potential to facilitate the adoption of other nature based solutions that have environmental and agromic benefits. Specifically, reduced tillage systems can also improve soil structure and function and reduce costs. However, the transition to reduced tillage systems is often associated with short term soil compaction and the build up of weeds. By combining reduced tillage with compost and cover crops, these negative impacts can be mitigated.



BENEFITS OF COMPOST AND COVER CROPS FOR SOIL HEALTH AND YIELD

trans4num solution

Compost (at 30 t/ha wet weight) has been added to two trials in the UK on contrasting soil types alongside the growing of over winter cover crops for eight years. The compost and cover crops solution is implemented in different cropping rotations and either in an annually ploughed or reduced tillage system.

Where compost was applied preceding winter wheat, yield increased by an average of 4% and 9% on the sites with sandy loam and clay loam soil respectively. There is, therefore, potential to reduce autumn fertiliser applications at both sites. On the site with a sandy loam, residual nitrogen measured in the spring remained higher on winter wheat plots where compost had been applied, providing a further opportunity to reduce spring applied fertiliser. However, on the site with a higher clay content any remaining additional nitrogen released from the compost over winter was locked up in mineral aggregates and not available to the crop.

Spring barley yields only benefitted from compost at the sandy loam site, with average increases of 18% - there were no benefits for spring crops at the clay loam site. This reflected the fact that bioavailable nitrogen was reduced on the soil with a higher clay content because of a higher proportion of mineral associated organic matter (MAOM). Potential for organic substitution of synthetic fertiliser in spring crops was, therefore, limited to the sandy-loam site. However, this potential is greater on plots with reduced tillage as there was a synergistic effect of tillage and compost + cover crops.

A high biomass of over winter cover crops had a negative impact on spring barley yields at the clay-loam site. Again, this reflects the fact that a larger proportion of soil organic matter is protected in mineral aggregates; by acting as a catch crop, over winter biomass soaks up any remaining bioavailable nutrients at this site, limiting access for a following spring crop. Cover crops may not, therefore, be beneficial on heavier soils.

Soil organic carbon has increased on plots with reduced tillage and additions of compost at both sites but increases are larger and more consistent at the clay-loam site reflecting the contrasting capacity of the soils to protect carbon in mineral aggregates. Associated longer term benefits for soil function are expected to result in better yield resilience in future analyses.



What were the challenges / limitations in the implementation process?

- The main challenge to the implentation of this solution is the availability of compost and the cost ot transport.
- The potential for reducing rates of synthetic fertiliser will also vary between fields and years depending on the cycling of nutrients and growth of cover crops. Robust decision support is required to support this opportunity.



What kind of resources do you need to implement the proposed solution?

- A field level digital twin or decision support tool that combines modelling with in field monitoring of nutrient cycling, soil moisture and crop growth would be a valuable tool for adapting crop nutrition strategies and reducing synthetic fertiliser use.

BENEFITS OF COMPOST AND COVER CROPS FOR SOIL HEALTH AND YIELD

More information

- Learn more about the trans4num UK site
- Explore more Practice Abstracts













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FROM ANIMAL WASTE TO PLANT NUTRITION

Summary

Domestic livestock make a number of valuable food and material products, but at the end of their life the skeleton and unused parts are often lost from the agricultural system. The bones of animals contain a valuable resource in the form of hydroxyapatite - a form of calcium phosphate. Conversion of the hydroxyapatite into a plant available form of phosphorus can be utilised to produce a fertilizer. Field trials have demonstrated that the use of this type of phosphorus has a comparable benefit to crop yields as conventional phosphorus fertilizers.

The need

Fertilization is one of the key components in modern agriculture. Without the application of fertilizers, crops must utilise what nutrients are available within the soil. High yielding crops quickly deplete the reserves of nutrients found within the soil, and natural rates of deposition are not sufficient to replace what is being taken out of the system within the crops. Therefore, the nutrients must be replaced with fertilizers in order to maintain the yields necessary to feed the population.

Mining allows vast mineral resources to be relatively quickly pulled from the ground and processed into material that is both easy for farmers to apply to their crops, and accessible by the plant roots. However, two problems exist with the primary resource used to manufacture phosphorus fertilizers - rock phosphate.

Firstly, 80% of the global reserve of rock phosphate is found in Morocco and Western Sahara, and geopolitical tensions in this area mean that supplies may be interrupted at short notice. Secondly, rock phosphate sometimes has a high cadmium content, and contamination of land with this heavy metal needs to be avoided.

The recycling of phosphorus from animal bones into a phosphorus fertilizer would avoid these issues.



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The benefits

The alternative phosphorus fertilizer used in this field trial has a number of benefits compared to the use of rock phosphate as a raw ingredient.

Firstly, the recycling of waste material from the livestock industry can provide an alternative source of phosphorus to the mining of rock phosphate. Sufficient production to meet the entire needs of an individual country is unlikely, but could form the foundation of a phosphorus fertilizer production system across many countries.

Secondly, the cadmium contamination of agricultural soils would be avoided if a significant proportion of the phosphorus needs are met by applying a fertilizer that does not contain this contaminant.

Thirdly, the use of animal bones and other material from abattoir systems, when used to manufacture a fertilizer, will also contain some of the other nutrients required by the crop plants. For example, the total phosphorus and sulphur needs of a winter wheat crop can be met with this single fertilizer, as well as 6% of the crop's nitrogen requirement and 8% of its potassium needs. This would have the dual benefit of reducing the use of the world's resources for agriculture, as well as cutting the costs to farmers when buying multinutrient fertilizers.

Lastly, should a new industry be developed that uses a waste material from the livestock industry to manufacture a useful product, it could increase the monetary value of each animal being produced.



FROM ANIMAL WASTE TO PLANT NUTRITION

trans4num solution

A field trail over multiple years was undertaken at the Rothamsted Research experimental station located at North Wyke in the south west of England. A grass silage system as well as pre-winter sown arable crops were utilised in the trial.

Three fertilizer application regimes were used in the trial:

- Standard fertilizers available on farm and all commercially available,
- A novel fertilizer manufactured using waste material from the livestock industry,
- A nil input control to allow the crops to grow using only what was available within the soil.

Standard fertilizer application rates were utilised in the study following the U.K. government's fertilizer recommendations for each particular crop. Soil samples were taken prior to any fertilizer applications, and only what was needed to meet the nutrient needs of the crop was applied. Four main nutrients were included in the trial: phosphorus, nitrogen, potassium and sulphur.

Where the **novel fertilizer** did not meet the requirements of the crop being grown, the commercially available fertilizers were added to supplement what was needed. This resulted in the total amounts of the four nutrients being applied at the same rate in the fertilized plots, with only the form of the application differing between treatments.

The results from the field trials illustrate that the fertilized crops produced better yields than the **nil fertilized** control plots. There were no significant differences between the two fertilizer treatments for grass silage or winter wheat crops.

We can conclude that the use of a novel fertilizer manufactured from animal waste materials such as bones can be used to produce a fertilizer that is comparable to the standard phosphorus fertilizer available on the market today. Detailed nutrient analysis will be undertaken to examine whether there are any beneficial effects on the crop when using the novel fertilizer, as was found in controlled environment pot trails when using this product (Darch et al., 2019, Frimpong et al., 2024).



What were the challenges / limitations in the implementation process?

- **Business development issues>:** technical challenges of getting a product to market
- **Consumer acceptance:** difficulty in shifting users from a known product to a novel product
- **Economic issues:** high energy costs associated with manufacturing
- **Farmer mindset:** historical use of commodity pricing to determine the purchase and use of phosphorus fertilizers



What kind of resources do you need to implement the proposed solution?

- **Government support:** tighter control on phosphorus applications to crops in light of recent eutrophication of rivers in the U.K. involving phosphorus.
- **Business Development Strategy:** government support for Small and Medium Sized Enterprises to break into an existing market.
- **Knowledge Exchange:** effective interpretation and presentation of scientific evidence to persuade agronomists to use a novel fertilizer.

FROM ANIMAL WASTE TO PLANT NUTRITION

More information

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- Explore more Practice Abstracts: https://trans4num.eu/library/?type=ABS








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EXPERIENTIAL AND MOBILE TOOLKIT FOR CLIMATE-RESILIENT AGRICULTURE AND SOIL REGENERATION

Summary

The theoretical benefits of nature-based solutions (NBS) are well established, yet farmers and advisors consistently report that available information remains abstract, real-world examples are scarce, and the principles of NBS are difficult to translate into everyday practice. The **NBS Toolkit**, developed within the trans4num project, was created in direct response to this challenge: it establishes an experiential learning environment in which farmers, advisors and students can tangibly discover what NBS look like in practice.

The need

Climate change and intensive farming pose a direct threat to soil life, water balance and nutrient cycling. Feedback gathered at trans4num project meetings made one thing clear: stakeholders are frustrated by contradictory and hard-to-interpret information.

NBS remain conceptual, and the processes of soil degradation are largely 'invisible' in daily life: what happens beneath the surface simply cannot be seen.

The **NBS Toolkit** bridges this knowledge gap by making the hidden processes of the soil visible and comprehensible, establishing a direct link between principle and reality.



The benefits

- **Immediate visualisation**: NBS Tools make the invisible visible — the links between soil erosion, compaction and healthy soil life are demonstrated directly through hands-on experiments.
- **Risk-free simulation**: Acting as a 'future simulator', the toolkit allows farmers to test their ideas in a safe environment and receive immediate feedback on the potential impacts of their decisions.
- **'Seeing is believing' experience**: The toolkit dissolves uncertainty around NBS techniques, providing farmers and advisors with tangible evidence of the effectiveness of sustainable practices.
- **A bridge between generations**: Story-driven content developed with young people through co-creation, using comic-style illustration, makes complex scientific connections emotionally accessible to all age groups.
- **Social dialogue**: The toolkit connects policy objectives with physical reality, facilitating communication and shared responsibility among farmers, decision-makers and local communities.



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EXPERIENTIAL AND MOBILE TOOLKIT FOR CLIMATE-RESILIENT AGRICULTURE AND SOIL REGENERATION

trans4num solution

Developed by the Pisztráng Kör Association, the **NBS Tools** are a fully mobile, modular and scalable learning ecosystem designed to make nature-based solutions visible, understandable and interactive.

The toolkit departs from the methodology of abstract educational materials. In their place, portable, tactile and story-driven physical models allow participants to directly observe, compare and test real agricultural processes. Integrated into wheeled demonstration cabinets (housing a wind tunnel, rain simulator, soil compaction tester and worm hotel) and complemented by analogue, page-turning information carriers, the toolkit is immediately deployable in indoor classrooms, professional events and outdoor demonstration sites alike.

The innovation is grounded in the integration of real biological and farming patterns:

- **Diverse soil samples**: Side-by-side comparisons of different cultivation methods (conventional vs. sustainable, compacted vs. optimal structure, bare vs. covered surface) deliver immediate, tangible insights.
- **Living organisms**: The worm composter and multi-layered mini soil profiles featuring live earthworms, demonstrate active soil life and the process of biological loosening.
- **Living vegetation**: Various cover crops and vegetative elements illustrate the benefits of crop rotation, nutrient cycling and biological erosion protection.

Operating the tools produces rapid and measurable results, bringing to life the 'seeing is believing' experience that participants consistently highlight in their feedback.

The toolkit is built on two main tool categories:

1. **Observation & Problem-Raising Tools** — spark curiosity and help identify root problems (e.g. the soil management causes behind dust storms and mudflows).
2. **Investigation, Analysis & NBS Exercise Tools** — enable participants to test their own hypotheses, model physical processes, and deepen their understanding of nature-based solutions.

The modular structure ensures that the depth and focus of the message always adapts to the needs of the target audience: from farmers and advisors seeking practical evidence, to policymakers visualising strategic goals, to school groups, university students and the general public.



What were the challenges / limitations in the implementation process?

Development and testing revealed a clear finding: digital solutions (e.g. digital picture frames, embedded audio) restrict mobility due to power requirements, particularly at field-based demonstrations. Analogue, page-turning information carriers proved consistently more reliable and robust. A physical constraint is the considerable weight of glass containers filled with soil, which demands careful attention during transport. The effectiveness of the tools is also strongly dependent on the methodological competence of the facilitator: the best results are achieved with a trained, experienced presenter.



What kind of resources do you need to implement the proposed solution?

- **Local craftsmen and designers**: The involvement of carpenters, metal and plastics technicians, and graphic designers is essential for manufacturing the physical structures and developing the visual identity.
- **Methodologically trained educators and advisors**: Effectively running the programmes requires qualified environmental educators, agricultural advisors or engineers capable of facilitating both problem-raising and solution-oriented processes.
- **Ongoing maintenance resources**: The long-term operation of a toolkit built on a living ecosystem demands regular, planned maintenance as a core operational requirement.

EXPERIENTIAL AND MOBILE TOOLKIT FOR CLIMATE-RESILIENT AGRICULTURE AND SOIL REGENERATION

Practical recommendations for users

- **Co-creation and local embedding**: Before introducing the tools, it is advisable to organise joint workshops with local educational institutions, researchers and farmers (as demonstrated by the trans4num INSPIRE Hackathon) to ensure that local specificities are genuinely built into the practices.
- **Structured learning pathway**: Demonstrations should follow the four-pillar methodological sequence: engaging storytelling → visual modelling → interactive experimentation → systemic strategic dialogue. This sequence ensures that participants not only see but also understand and internalise the lessons.
- **Routine maintenance:** Since the tools contain real soil and living organisms, their care requires regular, dedicated attention. Earthworms need feeding, plants need watering, and the soil in glass containers must be fully replaced every 3–4 months to prevent algae growth and the blurring of layer boundaries caused by intensive earthworm activity. Before transport, fixings should be checked to avoid damage.

Next steps & scaling

- Following the close of the project, NBS Tools operates as a permanent base at the Szigetköz Élményközpont (Szigetköz Experience Centre). Its mobile format, however, provides an excellent foundation for adaptation to other regions, new NBS types and future EU-funded projects contributing to the development of a growing European sustainability knowledge network.
- Explore the tools: https://trans4num.eu/en/trans4num-nbs-tools/
- Find more Practice Abstracts: https://trans4num.eu/library/?type=ABS








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SOIL PROFILE DISPLAY

Summary

The Soil Profile Display at Tündérsziget Ökopark in Dunasziget, Hungary, is a living outdoor classroom developed within the trans4num project. Through three full-depth soil profiles, visitors can directly observe authentic soil layers, root systems, and biological activity beneath the surface. Together with the trans4num NBS Tools, the installation creates a complete learning journey that connects hands-on experimentation with real-world landscape processes, making soil health and nature-based solutions tangible for diverse audiences.

The need

Healthy soils are fundamental for food production, water management, biodiversity, and climate resilience. However, most soil processes occur underground and remain largely invisible, making them difficult to understand and appreciate.

In the Szigetköz region, centuries of river regulation and water management have significantly altered the natural floodplain landscape and influenced soil development. Understanding how soils function, how roots shape soil structure, and how agricultural practices affect long-term soil health is essential for promoting sustainable land management.

There is therefore a need for educational tools that can transform complex soil processes into visible, understandable, and engaging learning experiences.



The benefits

The Soil Profile Display helps visitors see what is normally hidden beneath their feet.

Key benefits include:

- Visualising soil horizons and natural soil formation processes.
- Demonstrating the role of roots in soil regeneration and structure development.
- Showing the impacts of crop rotation, cover crops, legumes, and deep-rooting species.
- Increasing awareness of soil biodiversity and biological soil functions.
- Supporting practical learning about nature-based solutions.
- Encouraging sustainable agricultural practices and soil stewardship.
- Providing an engaging educational environment for schools, farmers, advisors, and policymakers.

The installation transforms soil science from an abstract concept into a direct and memorable experience.



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SOIL PROFILE DISPLAY

trans4num solution

The outdoor classroom consists of three excavated soil profiles located beside the Szigetköz Experience Centre. The profiles were excavated to a depth of 230 cm and carefully preserved behind reinforced glass panels, allowing visitors to observe authentic soil layers and living root systems throughout the year.

Each profile is planted annually according to crop rotation principles and showcases different crop groups:

- Deep-rooting crops such as maize and sorghum.
- Nitrogen-fixing legumes such as lucerne and berseem clover.
- Cereals such as winter wheat and sand oats.
- Companion plants and cover crops that enhance soil biological activity.

The site is maintained using nature-based management practices including no-till cultivation, cover cropping, mulching, and compost application.

The Soil Profile Display forms an integral part of the wider trans4num NBS Tools ecosystem. The mobile toolkit acts as a portable laboratory, allowing participants to explore processes such as water infiltration, erosion, compaction, and soil structure through simple experiments. The outdoor classroom then reveals these same processes in a living landscape context. The relationship works in both directions:

1. From mobile to field

- The NBS Mobile Tools introduce key concepts through hands-on experimentation.
- Visitors arrive at the soil profiles already understanding ideas such as root functions, compaction, biological activity, and water movement.

2. From field to mobile

- Observations made at the soil profiles generate questions that can be explored through experiments using the mobile toolkit.
- Demonstrations such as rainfall simulation and soil compaction testing help explain the processes visible within the profiles.

Together, the two systems create a complete learning arc that connects controlled experiments with real-world ecosystems.



What were the challenges / limitations in the implementation process?

- Excavation and profile stabilisation require specialised expertise
- Long-term maintenance is needed to preserve soil structure and visibility
- Seasonal crop management is necessary to maintain educational value
- Interpretation and facilitation are essential to maximise learning outcomes



What kind of resources do you need to implement the proposed solution?

- Excavation and construction materials
- Reinforced glass viewing panels and protective covers
- Annual crop establishment and maintenance
- Educational interpretation materials
- Trained facilitators and educators
- Access to complementary NBS Mobile Tools for integrated demonstrations

SOIL PROFILE DISPLAY

Educational Experience

The Soil Profile Display outdoor classroom has successfully engaged:

- Kindergarten and primary school children
- Secondary school students
- Teachers and educators
- Farmers and agricultural advisors
- Gardeners and allotment holders
- Policymakers and decision-makers
- Visitors to the Ökopark

The soil profiles demonstrate that soil is a living system with a continuous capacity for renewal when biological processes are supported. They highlight the importance of considering soil biology alongside physical and chemical soil properties.

One of the most innovative aspects of the trans4num NBS Tools approach is the integration of the mobile toolkit with permanent demonstration sites such as the Soil Profile Display. Rather than offering isolated educational tools, the project provides a connected and scalable knowledge system that helps people understand the relationships between soil, water, farming practices, and ecosystem health.

Rooted in the soils of the Szigetköz region, this model can be adapted and replicated across Europe to support learning and adoption of nature-based solutions.

- Explore more Practice Abstracts: https://trans4num.eu/library/?type=ABS








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SOIL CO_2 EMISSION MONITORING

Summary

Soil processes are often invisible, making it difficult for farmers to assess whether sustainable practices are improving soil health. Within the trans4num project, soil CO_2 emission monitoring was tested as a practical tool to evaluate the impact of Nature-based Solutions (NBS) on soil biological activity, nutrient cycling, and carbon efficiency. By combining CO_2 measurements with soil, plant, and drone monitoring, farmers can make more informed decisions and better understand how their management practices influence long-term soil resilience.

The need

Many soil degradation processes remain unnoticed until crop performance has already declined. Declining biological activity, poor soil structure, reduced water retention, and inefficient nutrient cycling often develop gradually and are difficult to detect with visual observations alone. Farmers need practical monitoring tools that provide early information on soil functioning and help them evaluate whether Nature-based Solutions are delivering environmental benefits.

In the Szigetköz region of Hungary, these challenges are particularly relevant because agricultural production is exposed to changing groundwater conditions, drought risks, and strong natural soil variability.



The benefits

Soil CO_2 monitoring provides several practical benefits:

- Makes below-ground biological activity visible and easier to understand
- Helps assess whether NBS improve soil functioning
- Supports more precise nutrient management decisions
- Links climate mitigation objectives with everyday farm management
- Helps farmers identify spatial and temporal variability within fields
- Strengthens advisory services, demonstration activities, and farmer learning
- Supports long-term monitoring of regenerative agricultural practices



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SOIL CO_2 EMISSION MONITORING

trans4num solution

The trans4num project integrated soil CO_2 emission monitoring into a broader Nature-based farming system tested in Kimle, Hungary. The trial compared NBS with conventional intensive farming across a three-year rotation of durum wheat, sorghum, and soybean.

The Nature-based system combined: crop rotation, no-tillage farming, reduced herbicide and pesticide use, poultry manure pellets as bio-based fertiliser, biostimulants, winter cover crops and continuous crop and soil monitoring

CO_2 emissions were measured using a portable instrument and a closed-chamber method, alongside soil sampling, plant nutrient analysis, soil profile observations, drone monitoring, satellite imagery. The measurements were interpreted together, as a single CO_2 value cannot determine whether a system is improving or losing carbon.

Across all three crops, Nature-based systems consistently produced equal or lower CO_2 emissions per unit of harvested yield than conventional systems.

Key findings include:

- Lower CO_2 emissions were observed under Nature-based management for soybean, sorghum, and durum wheat
- Significant reductions were recorded for sorghum and durum wheat
- Nature-based systems improved carbon efficiency while maintaining comparable yields
- The results demonstrate the climate mitigation potential of Nature-based agriculture

The project also found that soil biological improvements become visible gradually. Positive trends were observed in:

- Organic carbon
- Organic matter
- Nitrogen cycling
- Soil biological activity

The strongest effects occurred in the top 0–30 cm soil layer.



What were the challenges / limitations in the implementation process?

- Soil CO_2 emissions vary greatly throughout the season
- Results are strongly influenced by temperature, moisture, and recent field operations
- Natural field heterogeneity can sometimes mask treatment effects
- A single measurement cannot provide reliable conclusions
- Long-term monitoring is needed because soil changes occur slowly



What kind of resources do you need to implement the proposed solution?

- **Equipment**: portable CO_2 sensors, closed-chamber measurement systems, soil moisture and temperature measurements, drone and satellite monitoring tools
- **Knowledge and advisory support**: farmer training on interpreting CO_2 measurements, advisory services combining multiple monitoring tools, data-driven nutrient management approaches
- **Long-term monitoring**: repeated measurements throughout the season, consistent protocols, multi-year datasets to identify trends

SOIL CO_2 EMISSION MONITORING

More information

Practical recommendations:

- Measure several times during the growing season.
- Record soil moisture, temperature, crop stage, and recent field operations.
- Compare treatments under similar weather conditions.
- Use CO_2 measurements together with soil, plant, and remote sensing data rather than as a stand-alone indicator.

Soil CO_2 monitoring transforms invisible soil processes into measurable information, helping farmers understand whether Nature-based Solutions are improving soil health, increasing resilience, and reducing agriculture's climate footprint.

Find out more about the trans4num Hungarian NBS site: https://trans4num.eu/en/sites/eu/hungary/

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SOIL & PLANT MONITORING: MONITORING-SUPPORTED DECISION-MAKING FOR EFFECTIVE NATURE-BASED SOLUTIONS

Summary

Climate change, soil degradation, and water scarcity are placing growing pressure on European agriculture. While nature-based solutions such as cover cropping, reduced tillage, and organic soil regeneration are increasingly promoted, farmers often struggle to detect early signs of soil stress and crop health problems in time to act.

The **Soil & Plant Monitoring approach** within the trans4num framework addresses this by making soil and crop conditions measurable, visible, and understandable. Through field observations, monitoring tools, and data-driven methods, farmers and advisors can better understand soil-plant processes, optimise resource use, and apply nature-based solutions more effectively.

The need

Many soil degradation processes remain invisible until crop performance has already declined. Compaction, reduced water retention, nutrient imbalance, and biological degradation develop gradually and are difficult to detect without systematic monitoring. Climate extremes (prolonged drought and irregular rainfall) place additional stress on both soils and crops.

Relying on visual observation alone leads to delayed interventions and inefficient use of water, fertilisers, and other inputs. Natural soil variability within a single field adds further complexity, as different layers and zones respond differently to tillage, nutrient applications, and weather events.

There is therefore a growing need for practical, field-level monitoring that enables early decision-making and helps farmers adapt nature-based solutions to local conditions, verifying the outcomes of agricultural trials while providing continuous guidance for nutrient management and adaptive field decisions.



The benefits

- **Early stress detection**: Monitoring allows farmers to identify soil and crop stress before severe damage develops.
- **Improved water management**: Soil moisture monitoring supports more efficient irrigation and better water-retention strategies.
- **Reduced input use**: Better understanding of soil and plant conditions can decrease unnecessary fertiliser and water application.
- **Improved nutrient management**: Real-time nutrient monitoring supports site-specific and crop-adapted fertilisation decisions.
- **Support for nature-based solutions**: Monitoring strengthens the effectiveness of nature-based and soil-regeneration practices.
- **Better understanding of soil variability**: Soil profile investigations and spatial analyses improve precision management.
- **Climate resilience**: Healthy soils and informed management improve the resilience of agricultural systems against drought and extreme weather events.
- **Data-driven decision-making**: Combining field observations with digital technologies enables more accurate and adaptive farm management.



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SOIL & PLANT MONITORING: MONITORING-SUPPORTED DECISION-MAKING FOR EFFECTIVE NATURE-BASED SOLUTIONS

trans4num solution

The **Soil & Plant Monitoring approach** combines field observations with digital and sensor-based tools to support sustainable soil management and climate adaptation. It integrates soil analyses, plant monitoring, and spatial assessment to better understand soil–plant interactions and strengthen the implementation of nature-based solutions.

Soil Monitoring

Key indicators, like moisture, temperature, structure, and organic matter, provide essential information about soil health, water availability, compaction, and erosion risks. Soil profile investigations go deeper, revealing stratification, root-zone conditions, and water movement processes that are invisible from the surface.

Continuous nutrient assessment allows farmers to understand nutrient availability and balance, adapting fertilisation to actual field conditions rather than fixed schedules. Additional methods such as soil respiration and CO_2 measurements offer further insight into biological activity, supporting more regenerative soil management.

Plant Monitoring

Plant monitoring tracks crop vitality, leaf colour, biomass, and vegetation indices to detect early stress (from drought, nutrient deficiency, or soil degradation) before yield losses occur. Leaf analyses assess nutrient uptake and crop physiology, while drone-based and multispectral imaging reveal spatial variability and differences in crop performance across the field.

Aligned with crop development stages and field treatments, plant monitoring data provides a real-time, site-specific basis for optimising nutrient applications and reducing unnecessary inputs.

Supporting Nature-Based Solutions

Monitoring results directly support nature-based solutions such as cover cropping, mulching, compost application, and reduced tillage. Understanding soil variability, nutrient dynamics, and soil–plant interactions allows farmers to select and adapt nature-based solutions precisely. For example, choosing cover crop species suited to specific soil structure and moisture conditions.

Monitoring thus becomes not only a performance-tracking tool, but a key element in implementing and optimising climate-resilient, nature-based agricultural management.



What were the challenges / limitations in the implementation process?

- **Timing and operational capacity**: Suitable windows for field operations are narrowing and becoming less predictable; Farmers may lack the capacity to act at the right moment, even when data indicate optimal conditions
- **Data availability and interpretation**: Fast access to reliable, real-time data is essential but not always achievable; Converting large data volumes into practical management guidance remains complex
- **Data integration and compatibility**: Combining sensors, drone imagery, lab analyses, and field observations is technically demanding; Differences in formats, scales, and methods limit the use of integrated monitoring systems in practice



What kind of resources do you need to implement the proposed solution?

- **Monitoring tools and methods**: Soil and leaf analyses, in-situ sensors, drone and satellite observations; Digital decision-support tools to interpret soil variability, crop conditions and ecosystem processes
- **Key practices supported by monitoring**: Cover cropping, reduced tillage, mulching, organic amendments, site-specific nutrient management
- **Advisory and knowledge inputs**: Farmer experience and advisory support for data interpretation; Adaptation of regenerative practices to local soil conditions and crop requirements

SOIL & PLANT MONITORING: MONITORING-SUPPORTED DECISION-MAKING FOR EFFECTIVE NATURE-BASED SOLUTIONS

Practical recommendations for users

- Select nature-based solutions based on local soil and crop conditions. For example, matching cover crop species to soil structure, moisture, and nutrient status
- Apply continuous soil and plant monitoring throughout the growing season, as regenerative management requires both spatial and temporal precision
- Align nutrient applications with crop phenological stage and actual demand to improve efficiency and minimise losses
- Use soil and leaf analyses before peak uptake periods to inform fertilisation, organic amendments and foliar applications
- Adapt tillage timing and intensity to actual soil conditions to improve structure, water management and nutrient availability while avoiding compaction
- Combine drone-based monitoring, spatial assessment and field observations to understand field variability and support precise regenerative management

Next steps & scaling

- Closer integration of monitoring into the practical implementation of nature-based solutions
- Faster real-time data access and improved decision-support tools to help farmers better time and adapt regenerative practices
- Stronger knowledge transfer, demonstration activities and advisory networks to support wider adoption
- More site-specific management (cover crop selection, nutrient management, precision tillage) to build long-term resilience and sustainability

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NO-TILLAGE SOYBEAN SYSTEMS FOR IMPROVED SOIL MOISTURE AND YIELD STABILITY

Summary

Soybean production in Northeast China is increasingly affected by soil degradation, moisture loss, rising production costs, and climate variability. Conventional tillage practices often disturb soil structure, accelerate moisture loss, and increase labour requirements. Within trans4num, researchers tested conservation agriculture approaches that reduce soil disturbance while maintaining productivity. Results show that no-tillage systems can improve crop establishment, reduce production costs, and support more resilient soybean production systems.

The need

Soybean is an important crop in Northeast China, but farmers face several challenges:

- Reduced soil moisture availability during crop establishment
- Increasing production costs linked to intensive tillage
- Weed pressure and unstable crop emergence
- Soil degradation caused by repeated soil disturbance
- The need to maintain yields while reducing environmental impacts



The benefits

The tested system delivers multiple benefits:

For farmers

- Lower fuel, labour, and machinery costs
- Improved crop establishment
- Higher yield potential
- Reduced tillage operations

For the environment

- Better soil moisture conservation
- Reduced soil disturbance and erosion risk
- Improved soil biological activity
- More efficient use of resources

For advisors and policymakers

- Practical pathway towards conservation agriculture
- Reduced environmental footprint without sacrificing productivity
- Scalable solution for large soybean-growing regions



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NO-TILLAGE SOYBEAN SYSTEMS FOR IMPROVED SOIL MOISTURE AND YIELD STABILITY

trans4num solution

The project compared four soybean production systems:

- No-tillage with row-specific seeding (NTRS)
- Strip tillage with row-specific seeding (STRS)
- Deep tillage with row-specific seeding (DTRS)
- Conventional ridge tillage (RTR)

The NTRS system combines direct seeding with minimal soil disturbance. Crop residues remain on the soil surface, helping retain moisture, regulate soil temperature, and protect soil structure.

Results (Y1–Y3)

Field trials demonstrated that NTRS:

- Increased soil temperature and moisture during early crop development
- Improved emergence rates by 2.7–4.7%
- Increased emergence speed and crop uniformity
- Reduced weed dominance and improved weed management timing
- Increased pod numbers and yield potential
- Reduced labour requirements and production costs
- Improved overall profitability compared with conventional systems

AKIS System

- The innovation is supported by a strong research-led AKIS involving:
  - Chinese Academy of Agricultural Sciences (CAAS)
  - Regional research institutes
  - Experimental stations
  - Demonstration fields
  - Farmer outreach activities
- Knowledge generation is currently driven primarily by research institutions, with increasing efforts to strengthen farmer engagement and practical demonstration activities.



What were the challenges / limitations in the implementation process?

- Adoption may be slow where conventional tillage is deeply established
- Performance may vary depending on local soil conditions
- Farmers may perceive higher risks during transition



What kind of resources do you need to implement the proposed solution?

- Specialised no-tillage machinery
- Advisory support
- Long-term monitoring
- Farmer training and demonstration activities

NO-TILLAGE SOYBEAN SYSTEMS FOR IMPROVED SOIL MOISTURE AND YIELD STABILITY

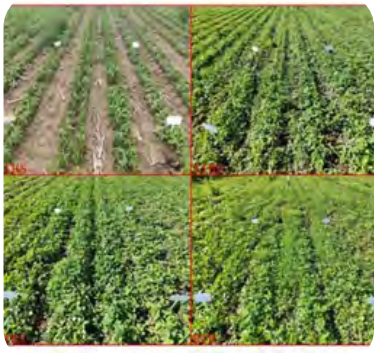
More information

Advisory and Policy Needs

- Successful scaling requires:
  - Farmer training programmes on conservation agriculture
  - Demonstration farms and peer-to-peer learning
  - Technical guidance on no-tillage management
  - Improved access to suitable seeding equipment
  - Incentives supporting reduced-tillage adoptio

Simple changes in tillage practices can improve soil conditions, increase profitability, and strengthen climate resilience while reducing production costs.

Explore more Practice Abstracts: https://trans4num.eu/library/?type=ABS













Learn more about the project at https://trans4num.eu/en/

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ORGANIC FERTILISER SUBSTITUTION TO IMPROVE SOIL CARBON AND NUTRIENT EFFICIENCY

Summary

Intensive vegetable and maize production systems in China often rely heavily on synthetic fertilisers, resulting in soil degradation, nutrient losses, and declining soil carbon levels. trans4num China tested different organic nutrient management strategies that partially replace chemical fertilisers with locally available organic resources. Results show that substantial reductions in fertiliser use can be achieved while maintaining yields and improving soil health.

The need

Farmers need sustainable nutrient management approaches that:

- Reduce dependence on mineral fertilisers
- Improve soil fertility and soil carbon stocks
- Reduce nutrient losses to the environment
- Maintain crop productivity
- Improve long-term resilience of farming systems



The benefits

For farmers

- Lower fertiliser requirements
- Improved nutrient-use efficiency
- Stable yields
- Improved soil fertility

For the environment

- Increased carbon sequestration
- Reduced nitrogen losses
- Improved soil structure
- Better nutrient cycling

For society

- Increased recycling of agricultural and food waste
- Reduced dependence on external fertiliser inputs
- Improved sustainability of food production systems



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ORGANIC FERTILISER SUBSTITUTION TO IMPROVE SOIL CARBON AND NUTRIENT EFFICIENCY

trans4num solution

The project tested partial substitution of chemical fertilisers in South-West China using:

- Biochar
- Chicken manure
- Food-waste-derived fertiliser
- Straw incorporation

In maize systems, organic substitution was combined with controlled-release fertilisers and improved nutrient management strategies.

Results (Y1–Y3)

Research showed:

- Significant improvements in soil carbon stability
- Improved soil aggregation and structure
- Maintained maize yields despite 37.5% lower nitrogen inputs
- Nitrogen surplus reductions of 75–77%
- Improved nitrogen-use efficiency
- Increased soil organic carbon under long-term straw return
- Biochar provided particularly strong improvements in carbon retention

AKIS System

The innovation is supported by:

- Southwest University
- Regional experimental stations
- Long-term field trials
- Research-led advisory activities

The AKIS remains largely research-driven, with opportunities to strengthen farmer participation and extension services.



What were the challenges / limitations in the implementation process?

- Organic materials vary in performance
- Nutrient release is slower than mineral fertilisers
- Risk of nutrient imbalances without proper management



What kind of resources do you need to implement the proposed solution?

- Organic amendment supply chains
- Soil testing and nutrient budgeting tools
- Technical advisory support
- Monitoring systems

ORGANIC FERTILISER SUBSTITUTION TO IMPROVE SOIL CARBON AND NUTRIENT EFFICIENCY

More information

Advisory and Policy Needs

- Nutrient management advisory services
- Farmer training on organic amendment use
- Support for circular nutrient systems
- Policies promoting recycling of organic waste streams
- Development of local supply chains for organic fertilisers

Organic fertiliser substitution can maintain yields while significantly reducing fertiliser inputs and improving soil health when supported by appropriate nutrient management.

Explore more Practice Abstracts: https://trans4num.eu/library/?type=ABS





Treatment	N (kg/ha)				P_2O_5 (kg/ha)			K_2O (kg/ha)	Note
	UN	CRUN	ON	Total	CP	OP	Total		
CK	0	0	0	0	90	0	90	55	One application as base fertilizer
FP	320	0	0	320	90	0	90	55	Split application of N with the ratio of Planting : Elongation : Flowering=3 : 3 : 4
OPT	100	100	0	200	90	0	90	55	One application as base fertilizer; CRUN (coated with polyurethane): 90-d N release period
IKPS	36	36	128	200	45	45	90	55	











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STRAW-BASED CROP–MUSHROOM SYSTEMS FOR CIRCULAR NUTRIENT USE AND SOIL RESTORATION

Summary

Millions of tonnes of crop residues are produced annually in China, yet much of this biomass remains underutilised. trans4num developed an innovative grain–mushroom rotation system that converts crop residues into valuable mushroom products while improving soil fertility, increasing crop yields, and creating new income opportunities. The system demonstrates how circular agriculture can deliver both environmental and economic benefits.

The need

Agricultural systems in the Henan region face:

- Declining soil organic matter
- Poor utilisation of crop residues
- Inefficient nutrient cycling
- Environmental impacts from residue management
- Pressure to increase productivity sustainably

The benefits

For farmers

- Additional income from mushroom production
- Higher grain yields
- Improved soil fertility
- Reduced weed pressure

For the environment

- Increased soil organic matter
- Enhanced carbon sequestration
- Improved nutrient recycling
- Reduced greenhouse gas emissions

For rural development

- New value chains and business opportunities
- Better utilisation of agricultural by-products
- Increased resource efficiency





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STRAW-BASED CROP–MUSHROOM SYSTEMS FOR CIRCULAR NUTRIENT USE AND SOIL RESTORATION

trans4num solution

trans4num China developed a grain–mushroom fixed-plot rotation system where:

- Wheat and maize straw are used as mushroom substrate
- Mushrooms are cultivated as a high-value product
- Spent mushroom substrate is returned to fields
- Grain crops and mushroom production rotate across plots

The approach transforms agricultural residues into valuable biological resources while improving soil quality.

The system delivered substantial benefits:

- Wheat yield increases of approximately 23.5%
- Soil organic matter increases exceeding 60%
- Available nutrient increases greater than 40%
- Weed reductions exceeding 90%
- Improved root development and photosynthetic efficiency
- Enhanced water-use efficiency
- Increased carbon sequestration
- Economic returns reaching up to €18,000/ha

The innovation combines:

- Research institutes
- Agricultural universities
- Demonstration farms
- Technology developers
- Machinery manufacturers

Future scaling will require stronger links with farmers, cooperatives, mushroom producers, processors, and local authorities.



What were the challenges / limitations in the implementation process?

- More complex management than conventional systems
- Requires specialised knowledge
- Initial investments may be required
- Dependence on market development



What kind of resources do you need to implement the proposed solution?

- Mushroom inoculum and cultivation materials
- Technical training
- Residue handling equipment
- Market access
- Advisory and extension support

STRAW-BASED CROP–MUSHROOM SYSTEMS FOR CIRCULAR NUTRIENT USE AND SOIL RESTORATION

More information

Advisory and Policy Needs

- Farmer training on mushroom cultivation
- Advisory services on substrate management
- Development of mushroom value chains
- Support for circular agriculture initiatives
- Incentives promoting residue valorisation

Crop residues can become a valuable resource. Grain–mushroom rotations improve soil fertility, increase farm income, and demonstrate how circular agriculture can contribute to sustainable food production.

Learn more:

- trans4num Europe - https://trans4num.eu/en/
- trans4num China - https://www.facisp.cn/nbs/index

Explore more Practice Abstracts: https://trans4num.eu/library/?type=ABS








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USING MODELLING TOOLS TO SUPPORT BETTER FARMING AND POLICY DECISIONS

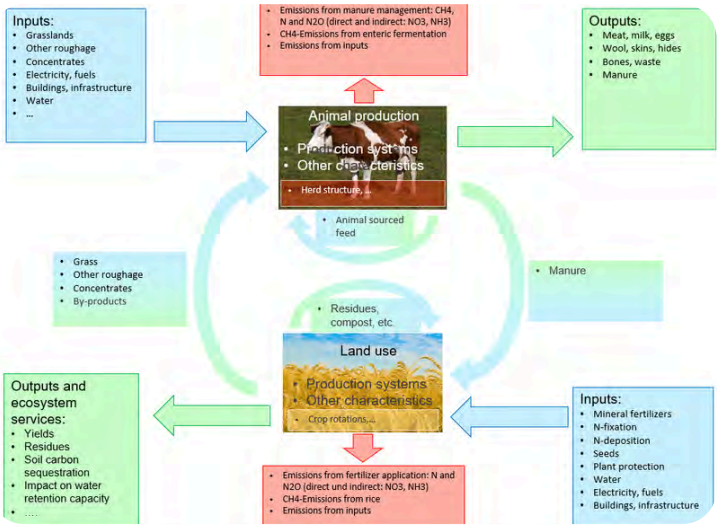
Summary

Nature-based Solutions (NBS) often require farmers and policymakers to make complex decisions involving environmental, economic, and social trade-offs. Within trans4num, a suite of complementary modelling tools was developed to support these decisions by exploring different future scenarios before actions are implemented. By combining Decision Support Tools (DST), Agent-Based Models (ABM), and Food System Models (FSM), stakeholders can evaluate the potential impacts of management practices and policy options, helping to reduce uncertainty and support more informed, evidence-based decision-making

The need

Farmers and policymakers need better ways to plan the transition to more sustainable agriculture. Decisions about nature-based solutions (NBS) are complex and involve trade-offs between productivity, environment, and costs.

However, many tools are too technical or poorly adapted to real-life decision-making. There is a need for models that reflect real-world conditions throughout the entire value chain, yet are sufficiently simple enough to provide farmers and policymakers with a clear, easy-to-interpret basis for decision-making.



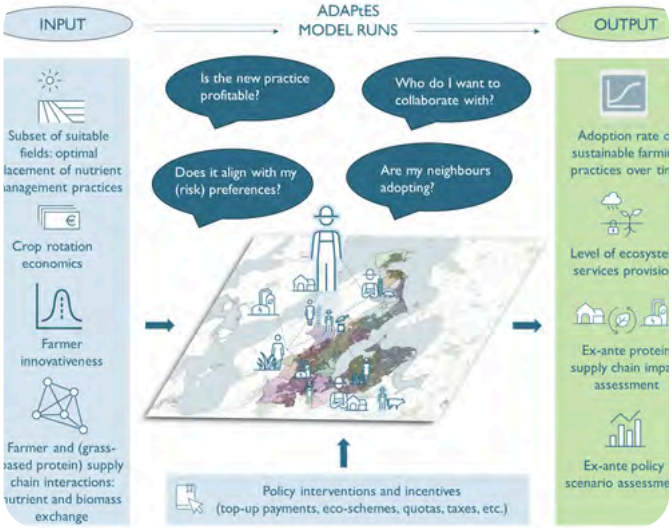
The benefits

Well-designed modelling tools help stakeholders understand future impacts before acting. They allow **farmers, advisors, and policymakers** to test different options, reduce risks, and make more informed decisions. This leads to better targeted policies, more effective incentives, and higher adoption of sustainable practices.

The models successfully help answer practical questions such as:

- What happens if new nitrogen policies are introduced?
- What if nature-based solutions are scaled up?
- What are the trade-offs between production, environment, and costs?

Early model applications (e.g. Danish ABM prototype) demonstrate the ability to show impacts on farmer behaviour, profitability, and environmental outcomes, supporting more realistic policy design. Stakeholder feedback highlighted that models must be easy to understand and transparent, otherwise they risk being seen as "black boxes" and not used.



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USING MODELLING TOOLS TO SUPPORT BETTER FARMING AND POLICY DECISIONS

trans4num solution

trans4num used three types of models for supporting the decision-making process:

- Decision Support Tool (DST): This explores how the spatial allocation of NBS practices can be optimized to reduce environmental impacts, improve ecological performance, and support agricultural productivity while balancing economic constraints across multiple spatial scales.
- Agent-Based Models (ABM): These simulate how farmers make decisions in real life, considering factors like costs, social influence, and policy incentives
- Food System Models (FSM): These explore how changes in farming practices and commodity processing and use affect food production, nutrient flows, and the environment at regional and national level

These tools were developed and tested together with stakeholders to ensure they are relevant, understandable, and useful in practice. They help answer "what if" questions before policies or investments are implemented and foster dialogue between different levels of stakeholders. Workshops with policymakers, advisors, and experts showed that models are more useful when developed together with users, ensuring they reflect real farming conditions, policies, and constraints and address the question of interest for various stakeholder groups.



What were the challenges / limitations in the implementation process?

- Models can be complex and difficult to understand and use without expert support (researchers and/or advisors)
- Results may not be trusted if tools appear as "black boxes"
- Differences between research timelines and policy needs can limit use
- Lack of data, incentives, or supportive policies can reduce real-world impact



What kind of resources do you need to implement the proposed solution?

- Skilled facilitators: experts who can explain results and guide discussions (reserachers and/or advisors)
- Stakeholder involvement: policymakers, advisors, and farmers engaged early
- Good data: reliable local and national data to improve model accuracy
- Balanced investment: equal focus on research, stakeholder engagement, and capacity building
- Intermediaries: organisations that connect science, policy, and practice

USING MODELLING TOOLS TO SUPPORT BETTER FARMING AND POLICY DECISIONS

More information

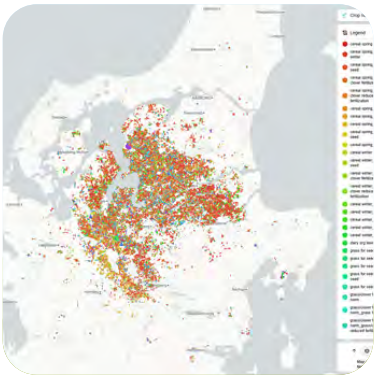
- Learn more about trans4num
- Explore the trans4num Decision support tool
- Explore more Practice Abstracts: https://trans4num.eu/library/?type=ABS













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HUNGARY: INTEGRATING NATURE-BASED SOLUTIONS FOR SUSTAINABLE NUTRIENT MANAGEMENT

Summary

The Hungarian NBS site demonstrates how multiple nature-based solutions can be integrated into a low-input arable farming system. Compared with conventional management, the NBS approach maintained plant nutrient status, improved soil-health indicators and reduced CO_2 emissions per unit of yield, particularly in sorghum and durum wheat. While yield performance varied by crop and season, the results highlight the potential of NBS to support climate-resilient farming. The case also emphasises the importance of long-term monitoring, advisory support and farmer demonstrations for successful adoption.

The need

The Hungarian NBS site responds to the need to make intensive arable production more resilient, lower-input and better aligned with the ecological sensitivity of the Szigetköz region. The trial area is located in a productive agricultural landscape that is also part of a Natura 2000 area, with high biodiversity value, wetland habitats and complex soil and hydrological conditions. This creates a dual need: maintaining viable crop production while reducing pressure on soils, biodiversity, nutrient cycles and climate.

The site also addresses a practical adoption gap. Many individual NBS practices are already known, but farmers need to see whether they can work together as a coherent farming system under real commercial-scale conditions. The case therefore focuses not only on agronomic performance, but also on demonstrating feasibility, monitoring needs and decision-support options for farmers.



The benefits

- Reduced climate pressure: CO_2-emission measurements showed consistently lower or equal emissions per unit of yield under NBS, with statistically significant reductions reported for sorghum and durum wheat in the later monitoring period.
- Maintained crop nutrition: leaf analyses showed no significant differences between NBS and conventional treatments, indicating that the NBS system maintained adequate plant nutrient status despite reduced reliance on conventional inputs.
- Positive soil trends: after three years, soil analyses indicated positive trends in organic carbon, organic matter, potentially mineralisable nitrogen and total nitrogen, especially in the upper 0–30 cm layer.
- Yield potential: durum wheat performed consistently well under NBS; in 2024, the NBS treatment delivered higher yields across durum wheat, soybean and sorghum, while 2025 results were more crop- and year-dependent.
- Biodiversity relevance: the Szigetköz landscape supports high bird diversity and includes protected and highly protected species, making biodiversity-sensitive farming especially relevant.
- Better decision-making: soil, leaf, drone, satellite and CO_2 monitoring support site-specific nutrient management rather than fixed input schedules.



Funded by the European Union

HUNGARY: INTEGRATING NATURE-BASED SOLUTIONS FOR SUSTAINABLE NUTRIENT MANAGEMENT

trans4num solution

The Hungarian NBS case demonstrates an integrated production system on a 20-hectare field in Kimle, comparing nature-based and conventional farming over a three-year rotation of durum wheat, sorghum and soybean.

The NBS package combines no-tillage, reduced pesticide use, poultry manure pellets, biostimulants, winter cover crops, mulching, and integrated crop and soil monitoring. Performance is assessed through soil and leaf analyses, drone and satellite imagery, NDVI, soil profiling and CO_2 measurements.
Rather than testing individual practices in isolation, the trial demonstrates that a complete NBS system can be successfully integrated into commercial farming while maintaining crop nutrient status and delivering environmental benefits. Monitoring also shows that drone imagery helps identify management zones and natural soil variability, supporting more precise field management.

The Hungarian NBS site AKIS links researchers, farmers, advisors, environmental educators and local stakeholders to support NBS adoption. Knowledge is shared through field demonstrations, workshops, questionnaires and farmer discussions. Events in Dunasziget and Mosonmagyaróvár brought together farmers, advisors and public authorities to exchange experiences and discuss implementation.

The main scaling pathway is to translate research findings into practical guidance, advisory recommendations and decision-support tools that help farmers identify where and how NBS can be successfully adopted.



What were the challenges / limitations in the implementation process?

- Soil-health improvements require long-term monitoring.
- Natural soil variability can mask treatment effects.
- Crop performance varies with seasonal climate conditions.
- NBS requires careful monitoring and technical support.
- Reduced pesticide use demands more adaptive crop management.
- Farmer adoption depends on confidence in the system's practicality and profitability.



What kind of resources do you need to implement the proposed solution?

- Bio-based fertilisers and suitable application equipment.
- Knowledge of no-till, crop rotation and cover crop management.
- Soil, crop and remote-sensing monitoring tools.
- Decision-support and data management systems.
- Farmer training and demonstration activities.
- Collaboration among farmers, advisors and researchers.

HUNGARY: INTEGRATING NATURE-BASED SOLUTIONS FOR SUSTAINABLE NUTRIENT MANAGEMENT

More information

- Find more about the Hungarian NBS site
- Read more Practice Abstracts
- Explore the NBS Tools
- trans4num legacy: the Green connections project
- Exploring soil, solutions, and learning: trans4num professional day in Hungary
- Building resilient soils in Hungary animation









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THE NETHERLANDS: INTEGRATING NATURE-BASED SOLUTIONS FOR SUSTAINABLE NUTRIENT MANAGEMENT

Summary

The Dutch NBS site investigates plant-based fertilisation at the Planty Organic experimental field as a circular alternative to animal manure. By using legume biomass grown within the crop rotation, the system aims to reduce dependence on external nutrient inputs while maintaining a balanced nutrient cycle at the farm level.

The results indicate that this adapted organic cropping system offers promising opportunities, but also faces important challenges. One of the main challenges is synchronising nutrient availability with crop nutrient demand throughout the growing season. In addition, further research is needed to assess the economic feasibility and scalability of the system for financially sustainable commercial farms, particularly in view of the potential impacts on crop yield and land use.

This case demonstrates that plant-based fertilisation can reduce dependence on external nutrient inputs and contribute to a more circular nutrient management system. At the same time, further research is required to better understand and quantify its long-term agronomic performance and economic impact.

The need

The Dutch case responds to the challenge of improving nutrient circularity and reducing reliance on external inputs in specialised arable systems. Organic arable farms without livestock often depend on externally sourced certified organic manure, which can be scarce and expensive.

The case also addresses the need to develop sustainable nutrient strategies for a region specialised in seed potato production and located near vulnerable Natura 2000 areas such as the Wadden Sea and Lauwersmeer. There is a need to maintain productivity while reducing dependence on synthetic fertilisers, animal manure and externally sourced nutrients.



The benefits

- Reduced dependence on organic manure by expanding the use of plant-based fertilisation sources, such as grass-clover, lucerne pellets, and harvested legume biomass.
- Greater nutrient circularity by growing part of the required nitrogen within the crop rotation and returning plant biomass to agricultural soils.
- Practical insight into timing and availability of nitrogen through the NDICEA model.
- Innovation opportunities for specialised arable systems, including possible future consumer interest in crops fertilised without animal inputs.
- Strong science-practice connection through SPNA field trials, farmer meetings, videos, newsletters, webinars and involvement of crop advisors.



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THE NETHERLANDS: INTEGRATING NATURE-BASED SOLUTIONS FOR SUSTAINABLE NUTRIENT MANAGEMENT

trans4num solution

The Dutch NBS site provides practical insights into the opportunities and challenges of using plant-based fertilisers. At the long-term Planty Organic trial, legume biomass is grown within the crop rotation, harvested, stored and returned to the field based on crop nutrient needs and decision-support modelling.

Additional trials evaluate plant-based fertiliser pellets in winter wheat, grass-clover fertilisation in organic wheat, and NBS measures in seed potato production, including straw and grass-based mulches to improve crop health and reduce aphid-related virus risks.

The Dutch AKIS brings together SPNA, Wageningen University, farmers and crop advisors to test, evaluate and promote NBS in practice. SPNA runs the field trials, while Wageningen University provides scientific monitoring and analysis.

Knowledge exchange takes place through field meetings, lectures, newsletters, social media videos and webinars. Meetings at Ebelsheerd and Kollumerwaard were organised to present the results of the various field trials to stakeholders. In addition, several hybrid meetings were held to broaden participation and increase the reach of the project.

A distinctive feature of the Dutch AKIS is the involvement of an experienced but traditional crop consultant during the growing season. At each important cultivation decision, common best practice is compared with NBS alternatives. This creates a practical bridge between innovation and daily arable decision-making, increasing the chance that NBS findings can be translated into advisory practice and wider uptake.



What were the challenges / limitations in the implementation process?

- Plant-based fertilisers require careful timing to meet crop nutrient demand.
- Supplementary spring nitrogen may improve performance.
- Long-term monitoring is needed to account for climate variability.
- Monitoring challenges required additional data collection.
- Successful adoption depends on farmer and advisor adaptation.



What kind of resources do you need to implement the proposed solution?

- Legume biomass production and storage facilities.
- Plant-based fertilisers (e.g. grass-clover or alfalfa pellets).
- Decision-support tools for nutrient planning.
- Soil and crop monitoring and analysis.
- Advisory support for NBS implementation.
- Farmer communication and knowledge-sharing activities.

THE NETHERLANDS: INTEGRATING NATURE-BASED SOLUTIONS FOR SUSTAINABLE NUTRIENT MANAGEMENT

More information

- Find more about the Dutch NBS site
- Read more Practice Abstracts
- A day in the field at SPNA








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UNITED KINGDOM: INTEGRATING NATURE-BASED SOLUTIONS FOR SUSTAINABLE NUTRIENT MANAGEMENT

Summary

The UK NBS site combines recycled fertilisers with long-term farming system experiments. At North Wyke, the recycled phosphorus fertiliser Thallo achieved yields comparable to conventional fertilisers, while the Large-Scale Rotation Experiment evaluates compost, organic amendments, crop rotations, reduced tillage and smart crop protection. The results show that NBS can reduce reliance on mineral fertilisers and improve soil health, but successful adoption depends on local conditions and careful management.

The need

The UK NBS site addresses the need to reduce reliance on conventional mineral fertilisers while maintaining crop productivity under increasingly variable climate conditions. The case is particularly concerned with phosphorus security, because conventional phosphorus fertiliser production depends heavily on rock phosphate resources concentrated in a limited number of geopolitically sensitive regions.

The UK NBS site also addresses the need for practical evidence on integrated NBS systems, including compost, organic amendments, crop rotations, reduced tillage and smart crop protection. Farmers require robust long-term evidence before adopting practices that may affect yield, pest pressure, disease risk, labour needs and profitability.

The benefits

- Bio-based phosphorus substitution: the Thallo fertiliser trial showed that grass and winter wheat fertilised with Thallo achieved yields significantly higher than the nil control and statistically equivalent to conventional fertiliser treatments under the tested conditions.
- Nutrient circularity: Thallo uses abattoir by-products, helping valorise livestock-sector waste and reduce dependence on rock phosphate.
- Potential micronutrient benefits: Thallo contains elements such as zinc, manganese and copper, which are not typically present in standard NPKS fertilisers.
- Soil carbon and resilience potential: compost and organic amendments can improve soil health and build soil carbon, although benefits depend on soil type and time horizon.
- Long-term evidence: the LSRE helps identify which combinations of rotations, tillage, organic amendments and crop protection are agronomically viable under real conditions.
- Risk screening: the UK work also identifies NBS approaches that may be too risky under certain weather, soil or disease conditions, improving the credibility of recommendations.





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UNITED KINGDOM: INTEGRATING NATURE-BASED SOLUTIONS FOR SUSTAINABLE NUTRIENT MANAGEMENT

trans4num solution

The UK NBS site work combines two complementary NBS platforms. The first is a replicated plot-scale fertiliser trial at North Wyke testing Thallo, a bio-based fertiliser made from agricultural and abattoir by-products, against conventional mineral fertilisers and a nil-input control. The trial includes grass ley and winter wheat, with nutrient rates aligned with UK fertiliser recommendations.

The second platform is the Rothamsted Large-Scale Rotation Experiment (LSRE), which tests combinations of crop rotation diversity, cultivation intensity, nutrition strategy and crop protection at two contrasting sites: Brooms Barn in Suffolk and Harpenden in Hertfordshire. The LSRE explores how compost, cover crops, organic amendments, reduced tillage and smart crop protection interact with soil type and climate variability.

The UK AKIS is centred on Rothamsted Research as a long-term experimental and knowledge-brokerage actor, connected to farmers, advisors, industry experts, agronomists, NGOs and policy stakeholders. The system combines scientific trials with stakeholder events that test how results can be made meaningful for practice.

Engagement activities included Research Insight days, soil-carbon workshops, LSRE field visits and events on pests, weeds, diseases and organic amendments. Participants included farmers, advisors, industry representatives, researchers, journalists, the Environment Agency, the NFU and organisations such as Farm Carbon Toolkit and Westcountry Rivers Trust.

The UK NBS site trial results cannot simply be handed to farmers as universal prescriptions. They need to be interpreted through farm priorities, soil conditions, climate risk and trusted advisory channels.



What were the challenges / limitations in the implementation process?

- Weather extremes affected crop establishment and performance.
- Some NBS practices increased yield or establishment risks under certain conditions.
- Disease pressure remains a challenge for some crop systems.
- Organic amendments require investment and long-term commitment.
- NBS performance depends on local soils, climate and management.
- Wider adoption of recycled fertilisers depends on market and regulatory acceptance.



What kind of resources do you need to implement the proposed solution?

- Access to recycled fertilisers and clear quality standards.
- Monitoring and advisory support for nutrient and crop performance.
- Infrastructure for producing and applying organic amendments.
- Long-term trials and data to assess system impacts.
- Advisory services to support local implementation.
- Collaboration among farmers, advisors, researchers and policymakers.

UNITED KINGDOM: INTEGRATING NATURE-BASED SOLUTIONS FOR SUSTAINABLE NUTRIENT MANAGEMENT

More information

- Find more about the British NBS site
- Read more Practice Abstracts
- Farmers and researchers explore the power of organic amendments at Rothamsted
- Closing nutrient loops in the UK | Nature-based solutions for farming animation








Learn more about the project at https://trans4num.eu/en/

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PROJECT - RESEARCH AND INNOVATION

Transformation for sustainable nutrient supply and management

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Discover website

Innovation, knowledge exchange & EIP-AGRI

ONGOING | 2022 - 2026

Denmark, Germany, Hungary, Netherlands, Romania, Switzerland, The United Kingdom, China

Context

trans4num is a four-year project funded under the Zero Pollution call as an EU-China international cooperation action on **nature-based solutions (NBS)** for nutrient management in agriculture.

trans4num is a multi-actor project, coordinated by the *University of Hohenheim,* which brings together partners from 14 European countries. Check the Partners section on our website for more details.

trans4num will asses innovative NBS practices in **4 European countries** and in 3 different locations in China. Check the NBS sites section for more details.

Objectives

trans4num ambition is to broadly enhance the NBS implementation in Europe with an integrative and tested multi-level approach, in dialogue with academic partners, practice partners and societal stakeholders by:

- **Identifying** and evaluating socially and contextually suitable transformation pathways towards a more sustainable nutrient management of N and P

- **Developing** a user-orientated decision support tool for regional nutrient management
- **Generating** and spreading practice-relevant assessments on the potentials of selected NBS for different agricultural systems, geographical and climatic zone
- **Setting-up, testing and promoting** a combined modelling of farm systems, value chain and food systems dynamics to generate robust multi-level evidence on the uptake and effects of innovative NBS
- **Promoting** outputs on NBS innovation

The objective is to develop and test innovative NBS practices and pathways that contribute to a socio-ecological transformation of existing intensive agriculture systems towards increasingly sustainable nutrient management.

- **SO1**. Develop, practice, and assess inter and transdisciplinary, systemic research conducive for a transformative learning approach towards sustainable agricultural practices.
- **SO2**. Develop a differentiated understanding of NBS potentials for sustainable agricultural practices in the context of intensive farming systems.
- **SO3**. Understand and analyse the complex interdependencies of applying NBS.
- **SO4**. Develop a dynamic and smart nutrient management tool to support decision making
- **SO5**. Provide an integrated assessment of food systems, value chains and policy levels' leverage points for a robust transition to nature-based nutrient management in Europe and China
- **SO6**. Develop evidence-based knowledge, create awareness for necessary conditions in a food system context, disseminate information and recommendations related to the design, development and implementation of NBS in different farming systems.
- **SO7**. Enhance Europe-China exchange and learning process.

Activities

The project activities are structured into six work packages (WPs):

WP1: Understanding NBS, concepts and approaches

Key activities include developing a conceptual framework based on existing knowledge, creating joint approaches for interdisciplinary analyses of NBS, and reviewing transformation pathways for applying innovative NBS.

WP2: Explore innovative NBS in regions of intensive farming

Key activities include creating an online inventory of promising NBS, implementing and testing NBS in different regions (Hungary, Denmark, Netherlands, UK, and China), and describing NBS cases as agricultural innovation systems.

WP3: Monitor and optimise NBS related nutrient flows

Key activities include monitoring nutrient flows using satellite data, developing a decision support system for nutrient supply, testing the decision support system in case regions, and engaging with technology development actors through hackathons.

WP4: Assess NBS effects in a SET context

Key activities include conducting agent-based farm-level modelling, creating participatory stakeholder involvement for the design of social innovation and NBS related SET, and performing comparative assessments of NBS cases in the EU and China.

WP5: Scaling up and out: Communication and dissemination

Key activities include developing a communication and dissemination strategy, creating multimedia activities and using social media, designing communication material and practice-oriented dissemination material for different audiences, organising regional and international events, and implementing policy dialogues.

WP6: Project coordination and management

Key activities include progress monitoring and reporting, administrative and financial management, data management and protection of intellectual property rights (IPR), and ensuring effective cooperation between European and Chinese partners.

Other comments

As a guiding principle, trans4num seeks to make research data openly available, whenever possible, in order to allow dissemination, validation and re-use of research results. To this purpose, trans4num project will make extensive use of open access resources to publish the work, outcomes and results. To this end trans4num project actively contributes to the EU-FarmBook and Zenodo platforms.

Project details

Main funding source

Horizon Europe (EU Research and Innovation Programme)

Type of Horizon project

Multi-actor project

Project acronym

trans4num

CORDIS Fact sheet

Project contribution to CAP specific objectives

- SO4. Agriculture and climate mitigation
- SO5. Efficient soil management
- SO6. Biodiversity and farmed landscapes
- Preserving landscapes and biodiversity
- Fostering knowledge and innovation

Project contribution to EU Strategies

- Reducing nutrient losses and the use of fertilisers, while maintaining soil fertility
- Improving management of natural resources used by agriculture, such as water, soil and air
- Protecting and/or restoring of biodiversity and ecosystem services within agrarian and forest systems

EUR 503 439 625.00

Total budget

Total contributions including EU funding.

EUR 461 712 338.00

EU contribution

Any type of EU funding.

Project keyword(s)

Arable crops

Circular economy, incl. waste, by-products and residues

Crop rotation/crop diversification/dual-purpose or mixed cropping

Biodiversity and nature

Agro-ecology

Food security, safety, quality, processing and nutrition

Landscape/land management Pest/disease control in plants Plant nutrients Soil

Water

Resources

Links

- Sister project - ECONUTRI
- PestNU project
- trans4num China project

Audiovisual materials

- LinkedIn
- YouTube
- BlueSky
- Newsletter

32 Practice Abstracts

Netherlands: Integrating nature-based solutions for sustainable nutrient management

The Dutch trans4num site investigates plant-based fertilisation as a circular alternative to animal manure. At the long-term Planty Organic experimental field, legume biomass grown within the crop rotation is harvested and returned to the soil to reduce dependence on external nutrient inputs while maintaining a balanced farm nutrient cycle. Results demonstrate the potential of plant-based fertilisation to improve nutrient circularity, although long-term agronomic and economic performance requires further evaluation.

The need

Specialised organic arable farms without livestock often rely on externally sourced organic manure, which can be scarce and expensive. The Dutch site addresses the need to develop more self-sufficient nutrient management systems for seed potato and arable production while reducing dependence on synthetic fertilisers, animal manure and imported nutrients. Located near vulnerable Natura 2000 areas, the site also seeks to maintain productivity while protecting sensitive ecosystems.

One of the main challenges is synchronising nutrient release from plant biomass with crop demand throughout the growing season. Additional research is needed to assess long-term productivity, land-use efficiency, economic feasibility and scalability under commercial farming conditions.

The benefits

- Reduced dependence on external organic manure through plant-based fertilisation.
- Greater nutrient circularity by recycling nitrogen within crop rotations.
- Decision support through the NDICEA nutrient model.
- New opportunities for specialised arable systems and animal-free fertilisation.
- Strong knowledge exchange through SPNA field trials, advisors and farmer engagement.

Explore: Netherlands: Integrating nature-based solutions for sustainable nutrie…

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Geographical Location

Netherlands

Additional information

trans4num solution

The Dutch site centres on the long-term Planty Organic experiment, where legume biomass is grown within the crop rotation, harvested, stored and reapplied according to crop nutrient requirements using decision-support modelling. Additional trials evaluate plant-based fertiliser pellets in winter wheat, grass-clover fertilisation in organic wheat, and straw- and grass-based mulches to improve crop health and reduce aphid-transmitted virus risks in seed potato production.

The Dutch AKIS brings together SPNA, Wageningen University, farmers and crop advisors to test, monitor and demonstrate NBS. SPNA manages the field experiments while Wageningen University provides scientific monitoring and analysis. Results are shared through field meetings, lectures, webinars, newsletters, videos and hybrid events.

A distinctive feature of the Dutch approach is the active involvement of an experienced crop consultant. Conventional farming recommendations are compared directly with NBS alternatives throughout the growing season, helping translate research findings into practical advisory guidance and increasing the likelihood of farmer adoption.

Challenges / limitations

Plant-based fertilisers require careful timing to match crop nutrient demand. Long-term monitoring is needed to capture climate variability, while successful implementation depends on farmer adaptation, advisory support and additional data collection.

Resources needed

Implementation requires legume biomass production and storage, plant-based fertilisers, nutrient planning tools, soil and crop monitoring, advisory services and continuous farmer knowledge exchange to support wider adoption.

United Kingdom: Integrating nature-based solutions for sustainable nutrient management

The UK trans4num site combines recycled fertilisers with long-term farming system experiments to demonstrate Nature-based Solutions (NBS) for sustainable nutrient management. At North Wyke, the recycled phosphorus fertiliser Thallo achieved yields comparable to conventional mineral fertilisers, while the Rothamsted Large-Scale Rotation Experiment (LSRE) evaluates compost, organic amendments, crop rotations, reduced tillage and smart crop protection. Together, the results show that NBS can reduce reliance on mineral fertilisers, improve soil health and support more resilient farming, although successful adoption depends on local conditions and long-term management.

The need

The UK site addresses the need to reduce dependence on conventional mineral fertilisers while maintaining crop productivity under increasingly variable climate conditions. Particular emphasis is placed on phosphorus security, as conventional phosphorus fertilisers rely on rock phosphate resources concentrated in a limited number of geopolitically sensitive regions.

The site also responds to the need for robust, long-term evidence on integrated NBS systems. Farmers require reliable information on how compost, recycled fertilisers, crop rotations, reduced tillage and crop protection influence yields, soil health, pest and disease pressure, labour requirements and profitability before adopting new practices.

The benefits

- Recycled phosphorus fertiliser produced yields equivalent to conventional fertilisers.
- Livestock by-products are recycled, reducing dependence on mined rock phosphate.
- Thallo supplies additional micronutrients, including zinc, manganese and copper.
- Compost and organic amendments improve soil carbon and resilience over time.
- Long-term experiments identify agronomically viable NBS combinations.
- Field trials improve confidence by identifying both opportunities and risks.

Explore: United Kingdom: Integrating nature-based solutions for sustainable nut…

Explore more trans4num Practice Abstracts

Geographical Location

United Kingdom

Additional information

trans4num solution

The UK site combines two complementary research platforms. The first is a replicated fertiliser trial at North Wyke comparing Thallo, a recycled phosphorus fertiliser produced from agricultural and abattoir by-products, with conventional mineral fertilisers and an unfertilised control in grass ley and winter wheat.

The second is the Rothamsted Large-Scale Rotation Experiment (LSRE), which evaluates combinations of crop rotation diversity, cultivation intensity, nutrition strategies and crop protection across contrasting soil types. The experiment investigates how compost, cover crops, organic amendments, reduced tillage and smart crop protection interact with soil conditions and climate variability.

The UK AKIS is centred on Rothamsted Research, linking researchers, farmers, advisors, industry, NGOs and policymakers through long-term experiments, field visits, workshops and stakeholder events. Results are translated into practical guidance through trusted advisory channels rather than universal recommendations, recognising that NBS performance depends on farm objectives, soil conditions and climate risks.

Challenges / limitations

Weather extremes, disease pressure and local soil conditions influence NBS performance. Organic amendments require long-term investment, while wider adoption of recycled fertilisers depends on market acceptance, regulatory frameworks and farmer confidence.

Resources needed

Successful implementation requires access to recycled fertilisers, quality standards, monitoring and advisory support, infrastructure for producing and applying organic amendments, long-term field experiments, and collaboration among farmers, advisors, researchers and policymakers.

Hungary: Integrating nature-based solutions for sustainable nutrient management

The Hungarian trans4num site demonstrates how multiple Nature-based Solutions (NBS) can be integrated into a low-input arable farming system. Compared with conventional management, the NBS approach maintained crop nutrient status, improved soil health indicators and reduced CO_2 emissions per unit of yield, particularly for sorghum and durum wheat. While yields varied between crops and seasons, the results demonstrate the potential of NBS to support climate-resilient farming. Long-term monitoring, advisory support and farmer demonstrations are essential for successful adoption.

The need

The Hungarian NBS site addresses the need to make intensive arable production more resilient, lower-input and better suited to the ecologically sensitive Szigetköz region. Located within a productive agricultural landscape that is also part of a Natura 2000 area, the site combines crop production with biodiversity conservation, soil protection and sustainable nutrient management.

The project also responds to a practical adoption gap. Although many NBS are already known, farmers need evidence that they can work together as a complete farming system under commercial conditions. The site therefore evaluates agronomic performance alongside monitoring approaches and decision-support tools that facilitate practical implementation.

The benefits

- Lower CO_2 emissions per unit of yield measured.
- Maintained plant nutrient status with reduced conventional inputs.
- Positive trends in soil organic carbon, organic matter and nitrogen.
- Crop yields maintained, with higher yields recorded for all crops in 2024.
- Site-specific nutrient management supported by soil, leaf, drone, satellite and CO_2 monitoring.
- Greater compatibility between productive farming and biodiversity conservation.

Explore: Hungary: Integrating nature-based solutions for sustainable nutrient m…
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Geographical Location

Hungary

Additional information

trans4num solution

The Hungarian demonstration site consists of a 20-ha commercial field in Kimle comparing Nature-based and conventional farming over a three-year rotation of durum wheat, sorghum and soybean.

The NBS system combines no-tillage, reduced pesticide use, poultry manure pellets, biostimulants, winter cover crops, mulching and integrated crop and soil monitoring. Performance is assessed using soil and leaf analyses, drone and satellite imagery, NDVI, soil profiling and CO_2 measurements.

Rather than evaluating individual practices separately, the trial demonstrates that an integrated NBS system can be successfully implemented under commercial farming conditions while maintaining crop nutrient status and delivering environmental benefits. Monitoring also shows that drone imagery can identify management zones and natural soil variability, supporting more precise nutrient management.

The site's AKIS connects researchers, farmers, advisors, environmental educators and local stakeholders through field demonstrations, workshops and farmer discussions. The main scaling pathway is to translate research findings into practical guidance, advisory recommendations and decision-support tools that help farmers identify where and how NBS can be successfully adopted.

Challenges / limitations

Soil improvements require long-term monitoring, natural variability can mask treatment effects, crop performance depends on seasonal conditions, and reduced pesticide use requires adaptive management. Farmer uptake also depends on confidence in the system's practicality and profitability.

Resources needed

Implementation requires bio-based fertilisers, suitable application equipment, knowledge of no-till and cover crop management, soil, crop and remote-sensing monitoring tools, decision-support systems, farmer training and close collaboration between farmers, advisors and researchers.

Scaling nature-based solutions through strong networks

Successful Nature-based Solutions (NBS) depend not only on innovative technologies but also on the people and organisations that support them. The trans4num project found that innovations are more likely to move beyond pilot projects when farmers, advisors, researchers, businesses and policymakers collaborate over time. Strong Agricultural Knowledge and Innovation Systems (AKIS), stable funding and continuous knowledge exchange help adapt innovations to local conditions and support their long-term uptake, while fragmented networks and short-term support limit wider adoption.

The need

Many promising NBS remain in early development because they lack strong networks connecting farmers, advisors, businesses and policymakers. Across Europe, weak coordination, missing actors and fragmented funding slow innovation and prevent solutions from becoming part of everyday farming practice.

The benefits

Well-functioning advisory and innovation networks improve farmers' access to practical knowledge, reduce risks and encourage the adoption of new practices. Strong cooperation between actors increases the likelihood that innovations are adapted to local conditions, become economically viable and receive long-term support from policy and markets.

Explore: Scaling nature-based solutions through strong networks

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Geographical Location

Denmark, Germany, Hungary, Netherlands, United Kingdom, Switzerland

Additional information

trans4num findings

trans4num showed that successful innovation depends as much on cooperation as on technology. Country examples highlighted different AKIS approaches:

• *Denmark*: Long-term cooperation between farmers, advisors, researchers and industry, supported by stable funding, enabled innovations such as green biorefineries to move beyond pilot projects.
• *Netherlands*: Farmer-led networks drove innovation, but limited formal support reduced long-term stability.
• *Hungary*: Top-down advisory systems and uneven access to knowledge limited farmer participation.
• *United Kingdom*: Product innovations developed by companies and researchers struggled to move beyond demonstration sites.

Farmers were more willing to test NBS when involved through co-design, testing and feedback. Trusted advisors translated research into practice, while strong networks, stable funding and broad stakeholder involvement enabled wider uptake. Diverse networks alone were insufficient when links between actors were weak.

Challenges / limitations

Missing key actors, weak coordination between policy, research and practice, fragmented funding and limited communication slowed innovation and reduced adoption.

Resources needed & policy recommendations

Successful implementation requires trusted advisory systems, inclusive networks, stable long-term funding, regular knowledge exchange through demonstration farms and peer learning, and coordination between science, policy and practice. AKIS should be supported by trusted innovation intermediaries rather than managed as a formal structure. The Danish experience highlights the value of regional multi-actor platforms, while the most appropriate coordination model should reflect the innovation, its development stage and the local institutional context.

Using modelling tools to support better farming and policy decisions

Nature-based Solutions (NBS) require farmers and policymakers to balance environmental, economic and social trade-offs. Within trans4num, a suite of complementary modelling tools was developed to explore future scenarios before actions are implemented. By combining Decision Support Tools (DST), Agent-Based Models (ABM) and Food System Models (FSM), stakeholders can assess the impacts of management practices and policy options, reducing uncertainty and supporting evidence-based decision-making.

The need

Farmers and policymakers need practical tools to plan the transition to more sustainable agriculture. Decisions on NBS involve trade-offs between productivity, environmental performance and costs, yet many existing models are either too technical or poorly adapted to real-world decision-making. There is therefore a need for models that reflect conditions across the entire value chain while remaining simple, transparent and easy to interpret.

The benefits

Well-designed modelling tools allow stakeholders to test alternative scenarios before implementation, reducing risks and improving decision-making. They support better targeted policies, more effective incentives and wider adoption of sustainable practices by answering practical questions such as:

- What happens if new nitrogen policies are introduced?
- What if nature-based solutions are scaled up?
- What are the trade-offs between production, environmental performance and costs?

Early applications, including the Danish ABM prototype, demonstrated the ability to assess farmer behaviour, profitability and environmental outcomes. Stakeholder feedback also highlighted that models must remain transparent and understandable to avoid being perceived as "black boxes".

Explore: Using modelling tools to support better farming and policy decisions

Explore more trans4num Practice Abstracts

Geographical Location

Denmark, Hungary, Netherlands, Switzerland, The United Kingdom

Additional information

trans4num solution

trans4num developed three complementary modelling approaches to support decision-making at different scales:

- *Decision Support Tool (DST)*: optimises the spatial allocation of NBS to reduce environmental impacts, improve ecological performance and maintain agricultural productivity while balancing economic constraints.
- *Agent-Based Models (ABM)*: simulate farmer decision-making by considering production costs, social interactions and policy incentives.
- *Food System Models (FSM)*: evaluate how changes in farming, commodity processing and resource use affect food production, nutrient flows and environmental performance at regional and national levels.

The tools were co-developed and tested with farmers, advisors, policymakers and researchers to ensure they remain relevant, understandable and practical. They support "what-if" analyses before

policies or investments are implemented and facilitate dialogue between stakeholders by reflecting real farming conditions, policy objectives and practical constraints.

Challenges / limitations

Models can be difficult to understand without expert support, results may be questioned if tools appear as "black boxes", differences between research and policy timelines can limit uptake, and limited data, incentives or supportive policies may reduce practical impact.

Resources needed

Successful implementation requires skilled facilitators, early stakeholder involvement, reliable local and national datasets, balanced investment in research, capacity building and stakeholder engagement, and intermediary organisations that connect science, policy and practice. Co-design with end users is essential to ensure modelling tools answer relevant questions and support informed, evidence-based decisions.

Straw-based crop–mushroom systems for circular nutrient use and soil restoration

Millions of tonnes of crop residues are produced annually in China, yet much of this biomass remains underutilised. Within the trans4num project, an innovative grain–mushroom rotation system was developed that converts wheat and maize straw into valuable mushroom products while improving soil fertility, increasing crop yields and creating new income opportunities. The system demonstrates how circular agriculture can generate both environmental and economic benefits.

The need

Agricultural systems in the Henan region face declining soil organic matter, poor utilisation of crop residues, inefficient nutrient cycling, environmental impacts from residue management and increasing pressure to improve productivity sustainably. Converting agricultural by-products into valuable resources offers an opportunity to restore soil health while strengthening farm resilience.

The benefits

For farmers

- Additional income from mushroom production.
- Higher grain yields.
- Improved soil fertility.
- Reduced weed pressure.

For the environment

- Increased soil organic matter.
- Enhanced carbon sequestration.
- Improved nutrient recycling.
- Reduced greenhouse gas emissions.

For rural development

- New value chains and business opportunities.
- Better utilisation of agricultural by-products.
- Increased resource efficiency.

Explore: Straw-based crop–mushroom systems for circular nutrient use and soil r…

Explore more trans4num Practice Abstracts

Geographical Location

China

Additional information

trans4num solution

trans4num China developed a fixed-plot grain–mushroom rotation system in which wheat and maize straw are used as mushroom substrate, mushrooms are cultivated as a high-value crop, spent mushroom substrate is returned to the fields, and grain and mushroom production rotate across plots. This circular approach transforms crop residues into valuable biological resources while improving soil quality and nutrient cycling.

The system delivered substantial benefits, including approximately 23.5% higher wheat yields, more than 60% increases in soil organic matter, over 40% higher available nutrient levels, weed reductions exceeding 90%, improved root development, photosynthetic efficiency and water-use efficiency, increased carbon sequestration, and economic returns of up to €18,000/ha.

AKIS system

The innovation brings together research institutes, agricultural universities, demonstration farms, technology developers and machinery manufacturers. Wider scaling will require stronger collaboration with farmers, cooperatives, mushroom producers, processors and local authorities.

Challenges / limitations

The system is more complex than conventional crop production, requires specialised knowledge and initial investment, and depends on the development of viable mushroom markets.

Resources needed & scaling

Successful implementation requires mushroom inoculum and cultivation materials, residue-handling equipment, technical training, advisory and extension services, and reliable market access. Wider adoption would benefit from farmer training, advisory support on substrate management, stronger mushroom value chains, incentives promoting residue valorisation and broader support for circular agriculture initiatives. Grain–mushroom rotations demonstrate how crop residues can become valuable

resources that improve soil fertility, increase farm income and contribute to more sustainable food production.

Organic fertiliser substitution to improve soil carbon and nutrient efficiency

Intensive vegetable and maize production systems in China often rely heavily on synthetic fertilisers, contributing to soil degradation, nutrient losses and declining soil carbon. Within the trans4num project, different organic nutrient management strategies were tested to partially replace chemical fertilisers with locally available organic resources. Results show that fertiliser use can be substantially reduced while maintaining crop yields and improving soil health.

The need

Farmers require sustainable nutrient management approaches that reduce dependence on mineral fertilisers, improve soil fertility and soil carbon stocks, minimise nutrient losses to the environment, maintain crop productivity and strengthen the long-term resilience of farming systems.

The benefits

For farmers

- Lower fertiliser requirements.
- Improved nutrient-use efficiency.
- Stable crop yields.
- Improved soil fertility.

For the environment

- Increased carbon sequestration.
- Reduced nitrogen losses.
- Improved soil structure.
- Better nutrient cycling.

For society

- Greater recycling of agricultural and food waste.
- Reduced dependence on external fertiliser inputs.
- More sustainable food production systems.

Explore: Organic fertiliser substitution to improve soil carbon and nutrient ef…

Explore more trans4num Practice Abstracts

Geographical Location

China

Additional information

trans4num solution

The project tested partial substitution of chemical fertilisers in South-West China using biochar, chicken manure, food-waste-derived fertiliser and straw incorporation. In maize systems, these organic amendments were combined with controlled-release fertilisers and improved nutrient management strategies.

Results (Y1–Y3) demonstrated significant improvements in soil carbon stability, soil aggregation and structure. Maize yields were maintained despite a 37.5% reduction in nitrogen inputs, while nitrogen surpluses were reduced by 75–77% and nitrogen-use efficiency increased. Long-term straw incorporation enhanced soil organic carbon, and biochar delivered particularly strong improvements in carbon retention.

AKIS system

The innovation is supported by a research-led AKIS involving Southwest University, regional experimental stations, long-term field trials and research-based advisory activities. While knowledge exchange is currently driven mainly by research institutions, there is considerable potential to strengthen farmer participation and extension services.

Challenges / limitations

Organic materials differ in nutrient content and performance, nutrients are released more slowly than from mineral fertilisers, and poor nutrient management can lead to imbalances.

Resources needed & scaling

Implementation requires reliable organic amendment supply chains, soil testing and nutrient budgeting tools, technical advisory support and monitoring systems. Wider adoption would benefit from nutrient management advisory services, farmer training, stronger support for circular nutrient systems, policies encouraging recycling of organic waste streams, and the development of local supply chains for organic fertilisers. Organic fertiliser substitution can maintain yields while substantially reducing fertiliser inputs and improving long-term soil health.

No-tillage soybean systems for improved soil moisture and yield stability

Soybean production in Northeast China is increasingly affected by soil degradation, moisture loss, rising production costs and climate variability. Conventional tillage disturbs soil structure, accelerates moisture loss and increases labour requirements. Within the trans4num project, conservation agriculture approaches were tested to reduce soil disturbance while maintaining productivity. Results show that no-tillage systems can improve crop establishment, lower production costs and support more resilient soybean production.

The need

Soybean growers face several challenges, including reduced soil moisture during crop establishment, increasing costs linked to intensive tillage, weed pressure, unstable crop emergence, soil degradation

caused by repeated soil disturbance, and the need to maintain yields while reducing environmental impacts.

The benefits

For farmers

- Lower fuel, labour and machinery costs.
- Improved crop establishment.
- Higher yield potential.
- Fewer tillage operations.

For the environment

- Better soil moisture conservation.
- Reduced soil disturbance and erosion risk.
- Improved soil biological activity.
- More efficient use of resources.

For advisors and policymakers

- A practical pathway towards conservation agriculture.
- Lower environmental footprint without sacrificing productivity.
- A scalable solution for large soybean-growing regions.

Explore: No-tillage soybean systems for improved soil moisture and yield stabil…

Explore more trans4num Practice Abstracts

Geographical Location

China

Additional information

trans4num solution

The project compared four soybean production systems: no-tillage with row-specific seeding (NTRS), strip tillage (STRS), deep tillage (DTRS) and conventional ridge tillage (RTR). The NTRS system combines direct seeding with minimal soil disturbance while leaving crop residues on the soil surface to conserve moisture, regulate soil temperature and protect soil structure.

Results (Y1–Y3) showed that NTRS increased soil temperature and moisture during early crop development, improved emergence rates by **2.7–4.7%**, accelerated emergence and crop uniformity, reduced weed dominance and improved weed management timing, increased pod numbers and yield potential, lowered labour requirements and production costs, and improved profitability compared with conventional systems.

AKIS system

The innovation is supported by a research-led AKIS involving the Chinese Academy of Agricultural Sciences (CAAS), regional research institutes, experimental stations, demonstration fields and farmer outreach activities. Knowledge generation is currently led by research organisations, with increasing emphasis on farmer engagement and practical demonstrations.

Challenges / limitations

Adoption may be slow where conventional tillage is well established, performance depends on local soil conditions, and farmers may perceive greater risks during the transition.

Resources needed & scaling

Implementation requires specialised no-tillage machinery, advisory support, long-term monitoring, farmer training and demonstration activities. Wider adoption would benefit from technical guidance, improved access to suitable seeding equipment, demonstration farms, peer-to-peer learning and incentives supporting reduced-tillage practices. Simple changes in tillage can improve soil conditions, increase profitability and strengthen climate resilience while reducing production costs.

Monitoring-supported decision-making for effective nature-based solutions

Climate change, soil degradation and water scarcity are placing increasing pressure on European agriculture. Although nature-based solutions (NBS) such as cover cropping, reduced tillage and organic soil regeneration are widely promoted, farmers often struggle to detect early signs of soil and crop stress. The Soil & Plant Monitoring approach developed within trans4num makes soil and crop conditions measurable through field observations, monitoring tools and data-driven methods, helping farmers optimise resource use and implement NBS more effectively.

The need

Many soil degradation processes (including compaction, reduced water retention, nutrient imbalance and declining biological activity) develop gradually and remain invisible until crop performance has already declined. Climate extremes such as prolonged drought and irregular rainfall further increase pressure on soils and crops. Reliance on visual observations alone often results in delayed interventions and inefficient use of water and fertilisers, while natural variability within fields complicates management decisions.

Practical field-level monitoring is therefore essential to support early decision-making, adapt NBS to local conditions, verify field trial results and guide nutrient management throughout the growing season.

The benefits

The monitoring approach:

- Detects soil and crop stress early.
- Improves water and nutrient management.

- Reduces unnecessary fertiliser and irrigation inputs.
- Supports implementation of NBS and soil regeneration.
- Improves understanding of soil variability.
- Strengthens climate resilience.
- Enables data-driven farm management by combining field observations with digital technologies.

Explore: Monitoring-supported decision-making for effective nature-based soluti…

Explore more trans4num Practice Abstracts

Geographical Location

Hungary

Additional information

trans4num solution

The Soil & Plant Monitoring approach combines field observations with digital and sensor-based technologies to better understand soil–plant interactions and support climate-resilient agriculture.

Soil monitoring measures moisture, temperature, structure, organic matter and nutrient availability while soil profile investigations reveal root-zone conditions, stratification and water movement that cannot be observed from the surface. Plant monitoring evaluates crop vitality, leaf colour, biomass and vegetation indices to detect early drought, nutrient or soil-related stress. Leaf analyses, drone imagery and multispectral observations reveal spatial variability and support site-specific nutrient management.

Together, these monitoring systems optimise NBS such as cover cropping, mulching, compost application and reduced tillage by adapting practices to local soil conditions and crop requirements. Monitoring therefore becomes both a performance assessment tool and a decision-support system for regenerative agriculture.

Challenges / limitations

Implementation is constrained by limited operational windows, the availability and interpretation of real-time data, and the complexity of integrating sensor, drone, laboratory and field observations into practical management decisions.

Resources needed

Successful implementation requires soil and leaf analyses, in-field sensors, drone and satellite observations, digital decision-support tools, advisory support and farmer experience to interpret results and adapt regenerative practices.

Practical recommendations

Carry out continuous monitoring throughout the growing season, align nutrient applications with crop demand, combine field observations with remote sensing, use soil and leaf analyses to guide fertilisation, and adapt tillage and NBS to local soil conditions. Closer integration of monitoring, improved DST and stronger advisory networks will support wider adoption of site-specific, climate-resilient agriculture.

Soil CO2 emission monitoring

Soil processes are largely invisible, making it difficult for farmers to assess whether sustainable practices improve soil health. Within the trans4num project, soil CO_2 emission monitoring was tested as a practical tool to evaluate the effects of nature-based solutions (NBS) on soil biological activity, nutrient cycling and carbon efficiency. Combined with soil, plant and drone monitoring, CO_2 measurements help farmers make more informed decisions and better understand how management practices influence long-term soil resilience.

The need

Many soil degradation processes develop gradually and remain unnoticed until crop performance declines. Reduced biological activity, poor soil structure, lower water retention and inefficient nutrient cycling cannot easily be detected through visual observation alone. Farmers therefore need practical monitoring tools that provide early information on soil functioning and help evaluate whether NBS deliver environmental benefits. These challenges are particularly relevant in Hungary's Szigetköz region, where agricultural production is affected by changing groundwater conditions, drought risk and strong natural soil variability.

The benefits

Soil CO_2 monitoring:

- Makes below-ground biological activity visible.
- Assesses whether NBS improve soil functioning.
- Supports more precise nutrient management.
- Links climate mitigation with everyday farm management.
- Identifies spatial and temporal variability within fields.
- Strengthens advisory services, demonstration activities and farmer learning.
- Supports long-term monitoring of regenerative agricultural practices.

Explore: Soil CO2 emission monitoring

Explore more trans4num Practice Abstracts

Geographical Location

Hungary

Additional information

trans4num solution

Within the trans4num project, soil CO_2 emission monitoring was integrated into a nature-based farming system tested in Kimle, Hungary, comparing NBS with conventional management across a three-year rotation of durum wheat, sorghum and soybean. The NBS system combined crop rotation, no-tillage, reduced herbicide and pesticide use, poultry manure pellets, biostimulants, winter cover crops and continuous crop and soil monitoring.

CO_2 emissions were measured using a portable closed-chamber system alongside soil sampling, plant nutrient analyses, soil profile observations, drone monitoring and satellite imagery. Because a single CO_2 value cannot determine whether soil is gaining or losing carbon, all measurements were interpreted together.

Across all three crops, NBS consistently produced equal or lower CO_2 emissions per unit of harvested yield than conventional systems, with significant reductions for sorghum and durum wheat. Carbon efficiency improved while maintaining comparable yields, demonstrating the climate mitigation potential of NBS. Long-term monitoring also showed gradual improvements in soil organic carbon, organic matter, nitrogen cycling and biological activity, particularly within the upper 0–30 cm of soil.

Challenges / limitations

CO_2 emissions vary with season, temperature, soil moisture and recent field operations. Natural field variability can mask treatment effects, making repeated, long-term measurements essential.

Resources needed

Implementation requires portable CO_2 sensors, closed-chamber systems, soil moisture and temperature measurements, drone and satellite monitoring, farmer training, advisory support and consistent multi-year monitoring protocols.

Practical recommendations

Measure CO_2 repeatedly during the growing season, record weather and management conditions, compare treatments under similar conditions, & always interpret CO_2 measurements together with soil, plant and remote-sensing data rather than as a stand-alone indicator.

Soil profile display

The Soil Profile Display at the Tündérsziget Ökopark in Dunasziget, Hungary, is a living outdoor classroom developed within the trans4num project. Through three full-depth soil profiles, visitors can observe authentic soil layers, root systems and biological activity beneath the surface. Together with the trans4num NBS Toolkit, it creates a complete learning experience linking hands-on experimentation with real-world landscape processes, making soil health and nature-based solutions (NBS) tangible for diverse audiences.

The need

Healthy soils underpin food production, water regulation, biodiversity and climate resilience, yet most soil processes occur underground and remain invisible. In the Szigetköz region, centuries of river

regulation and water management have reshaped the floodplain landscape and influenced soil development. Understanding how soils function, how roots shape soil structure, and how farming practices affect long-term soil health is essential for sustainable land management.

The Soil Profile Display addresses this challenge by transforming complex soil processes into visible, engaging and easy-to-understand learning experiences.

The benefits

The installation enables visitors to:

- Visualise soil horizons and soil formation.
- Understand how roots regenerate and structure soils.
- Observe the effects of crop rotation, cover crops, legumes and deep-rooting species.
- Increase awareness of soil biodiversity and biological functions.
- Support practical learning on NBS and sustainable soil management.
- Provide an engaging educational environment for schools, farmers, advisors and policymakers, transforming soil science into a memorable experience.

Explore: Soil profile display

Explore the NBS Toolkit

Explore more Practice Abstracts

Geographical Location

Hungary

Additional information

trans4num solution

The outdoor classroom consists of three excavated soil profiles, each 230 cm deep and preserved behind reinforced glass panels, allowing year-round observation of authentic soil layers and living root systems. The profiles are managed according to crop rotation principles and showcase deep-rooting crops, nitrogen-fixing legumes, cereals, companion plants and cover crops, while the site itself is maintained using no-till cultivation, cover cropping, mulching and compost application.

The Soil Profile Display is fully integrated with the trans4num NBS Toolkit. The mobile toolkit introduces concepts such as water infiltration, erosion, soil compaction and biological activity through practical experiments, while the outdoor classroom demonstrates these same processes under real field conditions. Together they create a complete learning pathway linking controlled experiments with living ecosystems.

Challenges / limitations

Successful implementation requires specialised excavation and profile stabilisation, continuous maintenance to preserve soil visibility, seasonal crop management, and skilled interpretation to maximise educational value.

Resources needed

Key requirements include excavation and construction materials, reinforced glass panels, annual crop establishment and maintenance, educational materials, trained facilitators, and access to complementary NBS Toolkit demonstrations.

Educational value & scaling

The Soil Profile Display has engaged school children, teachers, farmers, advisors, policymakers and visitors, demonstrating that soil is a living system capable of renewal when biological processes are supported. Combined with the NBS Toolkit, it forms a connected, scalable learning system that can be adapted and replicated across Europe to support the uptake of nature-based solutions.

Experiential and mobile toolkit for climate-resilient agriculture and soil regeneration

Although the benefits of nature-based solutions (NBS) are well established, farmers and advisors often find available information too abstract and difficult to translate into practice. Developed within the trans4num project, the NBS Toolkit creates an experiential learning environment where farmers, advisors and students can directly observe, test and understand NBS in practice.

The need

Climate change and intensive farming threaten soil health, water balance and nutrient cycling. Feedback from trans4num activities in Hungary showed that stakeholders are frustrated by contradictory information, while soil degradation processes remain largely invisible in everyday farming.

The NBS Toolkit addresses this gap by making hidden soil processes visible and understandable, linking scientific principles with real-world experience.

The benefits

The toolkit provides:

- Immediate visualisation by demonstrating soil erosion, compaction and healthy soil processes through hands-on experiments.
- Risk-free simulation, allowing users to test management decisions and immediately observe their potential impacts.
- A "seeing is believing" experience that reduces uncertainty around NBS by providing practical evidence of sustainable farming practices.
- Intergenerational learning, combining story-driven, comic-style materials co-created with young people to communicate complex concepts to all age groups.
- Social dialogue, linking policy objectives with practical realities and supporting communication between farmers, advisors, policymakers and local communities.

Explore: Experiential and mobile toolkit for climate-resilient agriculture and …

Explore the tools

Explore more Practice Abstracts

Geographical Location

Hungary

Additional information

trans4num solution

Developed by the Pisztráng Kör Association, the NBS Toolkit is a mobile, modular and scalable learning ecosystem that replaces abstract teaching with portable, tactile and story-driven demonstrations. Wheeled cabinets containing a wind tunnel, rain simulator, soil compaction tester and worm hotel, together with analogue information panels, can be used in classrooms, professional events and field demonstrations. The toolkit combines:

- side-by-side soil comparisons showing conventional and sustainable management, compaction and soil cover;
- living soil organisms, including earthworms, to demonstrate biological soil processes;
- living vegetation illustrating crop rotation, nutrient cycling and erosion protection.

Challenges / limitations

Digital components reduced mobility because of power requirements, making analogue solutions more reliable for field use. Transporting soil-filled glass containers requires care, while successful demonstrations depend on experienced facilitators.

Resources needed

Implementation requires local craftsmen and designers to build the toolkit, trained educators or agricultural advisors to facilitate learning, and regular maintenance of the living ecosystem, including plants, earthworms and soil.

Practical recommendations & scaling

Co-design with local farmers, researchers and educators is recommended, demonstrations should follow a structured learning sequence (storytelling → modelling → experimentation → dialogue), and routine maintenance is essential. The toolkit is permanently based at the Szigetköz Experience Centre but is designed for adaptation to other regions, NBS applications and future European projects.

From animal waste to plant nutrition

Livestock production generates valuable food and materials, but bones and other unused by-products are often lost from the agricultural system. Animal bones contain hydroxyapatite, a calcium phosphate mineral that can be converted into a plant-available phosphorus fertiliser. Field trials have shown that

this recycled phosphorus source can achieve crop yields comparable to conventional phosphorus fertilisers.

The need

Fertilisation is essential to replace nutrients removed through crop production and maintain agricultural productivity. Phosphorus fertilisers are mainly produced from mined rock phosphate, but this resource faces two major challenges. Around 80% of global reserves are located in Morocco and Western Sahara, making supplies vulnerable to geopolitical instability, while some rock phosphate contains cadmium, creating a risk of long-term soil contamination.

Recycling phosphorus from animal bones offers a circular alternative that reduces dependence on imported rock phosphate while avoiding cadmium contamination.

The benefits

The recycled phosphorus fertiliser provides several advantages:

- It recovers livestock waste and creates an additional domestic source of phosphorus, supporting more resilient fertiliser supply chains.
- It avoids cadmium contamination associated with some mined rock phosphate.
- Besides phosphorus, it also supplies other crop nutrients. For winter wheat, the fertiliser can provide the full phosphorus and sulphur requirements, together with around 6% of nitrogen and 8% of potassium needs, reducing fertiliser costs and resource use.
- Developing fertilisers from livestock by-products can create new value chains and increase the economic value of animal production.

Explore: From animal waste to plant nutrition
Explore more trans4num Practice Abstracts

Geographical Location

United Kingdom

Additional information

trans4num solution

A multi-year field trial was conducted at Rothamsted Research (North Wyke, UK) using grass silage and winter arable crops. Three fertiliser treatments were compared:

- conventional commercial fertilisers;
- a novel phosphorus fertiliser produced from livestock waste (animal bones);
- an unfertilised control.

Fertiliser applications followed UK recommendations. Soil nutrient status was assessed before application, and phosphorus, nitrogen, potassium and sulphur were supplied according to crop

requirements. Where the novel fertiliser alone could not fully meet nutrient demand, conventional fertilisers were added so that all fertilised treatments received equivalent nutrient inputs.

Fertilised crops consistently outperformed the unfertilised control, while no significant differences were observed between the recycled fertiliser and conventional fertiliser for grass silage or winter wheat yields. These results demonstrate that phosphorus fertiliser produced from livestock waste can perform as effectively as conventional phosphorus fertilisers. Further nutrient analyses will investigate additional crop benefits previously observed in controlled-environment studies.

Challenges / limitations

Key barriers include technical and business challenges in bringing the product to market, high manufacturing energy costs, farmer acceptance of a novel fertiliser, and established purchasing practices based on commodity pricing.

Resources needed

Successful implementation requires supportive phosphorus policies, business development support for SMEs entering the fertiliser market, and effective knowledge exchange to demonstrate the scientific evidence and build confidence among agronomists and farmers.

trans4num Decision support tool

The trans4num Decision Support Tool (DST) bridges the gap between farm-level nutrient management and landscape-scale environmental impacts. By linking field-level actions to broader outcomes, it helps farmers, advisors and policymakers plan and optimise nature-based solutions (NBS), visualise trade-offs, and collaboratively identify efficient, regionally adapted strategies for sustainable agriculture.

The need

Agricultural nutrient management decisions are usually made at farm or field level, while impacts such as nitrogen leaching, water pollution, biodiversity loss and soil degradation occur across landscapes. The DST was developed to bridge this mismatch by:

- linking field actions to landscape outcomes;
- visualising trade-offs between environmental objectives and agricultural productivity across different spatial scales;
- supporting the planning and implementation of NBS at landscape level; and
- fostering collaboration between farmers, advisors, policymakers and the wider bioeconomy sector.

The benefits

For farmers and farmer associations

- Demonstrates how field management influences landscape outcomes.
- Identifies new value chains, such as perennial grass or catch crops linked to green biorefineries.
- Evaluates realistic crop rotations rather than single-year crops or unrealistic farm redesigns.

- Supports cooperative decision-making across shared landscapes.

For advisors and policymakers
The DST facilitates dialogue between stakeholders, visualises environmental and economic trade-offs, strengthens advisory services by translating technical outputs into practical recommendations, supports collaborative policy design, and helps assess which policy options are feasible under real farming conditions.

Explore: trans4num Decision support tool

Explore the tool

Explore more Practice Abstracts

Geographical Location

Denmark, Hungary, Netherlands, United Kingdom, Switzerland

Additional information

trans4num solution

The DST is a spatially explicit, data-driven optimisation tool that evaluates the impacts of NBS under geographically varying conditions. Using mixed-integer programming, it allocates crop rotations and management strategies across landscapes. Transition matrices quantify how management changes affect nitrogen losses, yields and economic returns for different soil types, while field-level spatial data capture geographical variability. The tool combines a React-based interface with a Python backend and processes tabular and spatial datasets.

The DST supports discussion rather than prescribing decisions. Users first define regional objectives and constraints, after which the model identifies the most efficient spatial allocation of measures. If objectives are unrealistic, the tool highlights this. Outputs include optimisation maps, crop-share comparisons, radar charts comparing economic and environmental performance, and regional nitrogen balances.

Challenges / limitations

The DST is designed primarily for facilitated workshops rather than individual farm use. Applying it to new regions requires substantial local data, particularly transition matrices describing NBS performance under local conditions.

Resources needed

Implementation requires spatial agricultural datasets, clearly defined regional objectives, geographically explicit information on NBS effects, transition matrices describing management impacts, and a trusted facilitator such as a modeller, researcher or advisor.

Transferability

Developed for the Limfjord region in Denmark, the DST can be transferred to other regions by adapting objectives, constraints and local datasets. It was co-designed through transdisciplinary workshops with farmers, advisors and planners, and tested in Denmark, Hungary, the Netherlands and the UK, demonstrating its value for collaborative landscape planning.

Benefits of compost and cover crops for soil health and yield

The benefits of adding green compost to fields and growing cover crops depend on soil cultivation practices and local soil texture. In particular, the amount of clay in the soil influences nutrient availability and the retention of soil organic carbon.

The need

Rising synthetic fertiliser costs and their environmental impacts, including greenhouse gas emissions and nutrient leaching, have increased interest in organic amendments as nature-based solutions for sustainable nutrient management. Green municipal compost and over-winter cover crops can supply nutrients and improve soil health, but their effectiveness depends on the cropping system and local environmental conditions.

Compost and cover crops also increase soil organic carbon, helping restore soil structure, improve water infiltration and retention, and strengthen resilience to floods, droughts and climate change. Cover crop roots further enhance soil hydraulic conductivity by creating connected macropores.

To maximise the benefits of replacing synthetic fertilisers with organic sources, farmers and advisors need locally relevant evidence on crop and soil responses. Long-term monitoring is essential because improvements in soil health, nutrient cycling and resilience develop gradually and support informed decision-making.

The greatest benefits are achieved when compost and cover crops are combined with other nature-based solutions, such as diverse crop rotations and reduced tillage. This systems approach improves nutrient-use efficiency, supports healthier soils and helps overcome challenges associated with reduced tillage, including temporary soil compaction and weed pressure.

Explore: Benefits of compost and cover crops for soil health and yield
Explore more trans4num Practice Abstracts

Geographical Location

United Kingdom

Additional information

trans4num solution

Compost (30 t/ha wet weight) and over-winter cover crops were tested for eight years at two UK sites with contrasting sandy loam and clay loam soils under different crop rotations and conventional or reduced tillage.

Compost increased winter wheat yields by 4% on sandy loam and 9% on clay loam, creating opportunities to reduce autumn fertiliser applications. On sandy loam, residual nitrogen remained available in spring, allowing further reductions in spring fertiliser use. On clay loam, nitrogen released over winter became bound within mineral aggregates and was less available to crops.

Spring barley yields increased by 18% only on sandy loam soils. On clay loam, higher mineral-associated organic matter reduced bioavailable nitrogen, limiting the replacement of synthetic fertiliser. Reduced tillage enhanced the benefits of compost and cover crops through a synergistic effect.

High-biomass cover crops reduced spring barley yields on clay loam by capturing available nutrients before the following crop, suggesting that cover crops may be less suitable on heavier soils. Compost combined with reduced tillage increased soil organic carbon at both sites, with larger gains on clay loam, improving long-term soil function and crop resilience.

Challenges / limitations

The main constraints are compost availability, transport costs and the fact that fertiliser savings vary between fields and years depending on nutrient cycling and cover crop growth.

Resources needed

Field-scale digital twins or decision-support tools integrating nutrient cycling, soil moisture, crop growth modelling and field monitoring would help optimise fertiliser strategies and reduce synthetic fertiliser use.

AGRIFUTURE: Innovating crop rotations & soil health on clay soils

The goal of AgriFuture is to develop a future-proof crop rotation system that meets the needs of tomorrow’s farming practices. In this ‘farm of the future’, solutions are explored at the systems level for some of agriculture’s most pressing challenges, including:

- Herbicide-resistant weeds
- Limited availability of chemical inputs
- Rising production costs
- Declining water quality
- Extreme weather and climate change

By addressing these issues in an integrated way, AgriFuture is working toward a farming system that is not only ecologically and economically sustainable, but also resilient and innovative. The Oldambt crop rotation system is on the brink of a necessary renewal. To become more future-proof and sustainable, it needs a "version 2.0": a cropping system that not only offers economic viability for farmers but also contributes actively to addressing broader societal challenges .Key focus areas include:

- Reduced use of fertilizers and crop protection products
- Enhancing biodiversity
- Improving soil health
- Protecting water quality (EU Water Framework Directive)
- Climate adaptation

Several promising ideas for sustainable transition are already in motion — both at the Ebelsheerd experimental farm and among individual farmers in the region.

Examples of promising initiatives:

- Expanding crop rotations with legumes or mixed cropping systems
- Mechanical weed control and the use of robotics as alternatives to chemical inputs
- Collaborations between dairy and arable farms
- Use of organic by-products, such as compost or bokashi

By sharing knowledge and exchanging experiences, we are collectively shaping a renewed crop rotation system that is both profitable and environmentally responsible.

AGRIFUTURE: Innovating crop rotations & soil health on clay soils

Additional information

Goals for future-oriented arable farming:

- Develop a sustainable and future-proof Oldambt crop rotation system by 2030
- Achieve weed control and crop health without the use of substances listed under the CfS (Candidatesfor Substitution) list
- Significantly reduce the Environmental Impact Point System (MBP) at both farm and crop level
- Replace linear (synthetic) fertilizers with circular alternatives
- Implement climate-resilient water management tailored to the revised crop rotation
- Monitor soil health and biodiversity using Key Performance Indicators (KPIs)
- Map the CO_2 reduction potential of the cropping system
- Maintain or improve the financial profitability of the farm

Challenges

- Working toward long-term goals using the tools and knowledge available today
- Balancing innovation with practical applicability on real farms
- Ensuring that forward-looking solutions remain feasible in day-to-day operations
- Aligning different perspectives from farmers, researchers, and advisors
- Maintaining ongoing dialogue to support shared direction and decision-making

Resources

- Access to appropriate crop rotations, limiting cereals to a maximum of 50% and incorporating spring crops
- Machinery and/or robotics for effective weed control as an alternative to chemical herbicides
- Agronomic support and knowledge sharing to reduce reliance on chemical inputs, including the use of resilient crop varieties and optimal sowing strategies
- Understanding of circular agriculture opportunities in the region, including cooperation between arable and livestock farms
- Monitoring tools to track soil and crop health and guide adaptive management

AGRIFUTURE: Innovative crop strategies for seed potato cultivation

The AgriFuture project at Kollumerwaard focuses on seed potato cultivation as a key element within a future-proof crop rotation system. Seed potatoes come with specific demands regarding soil quality, crop rotation, and disease management, making them a relevant case in the transition toward more sustainable arable farming. The aim is to explore how seed potato cultivation aligns with the core principles of AgriFuture, such as:

- Reducing the use of chemical crop protection products
- Preserving and improving soil health
- Utilizing circular (organic) fertilizers
- Contributing to biodiversity and climate goals

The agricultural system is being shaped by a wide range of developments that call for an integrated approach and a clear vision for the future.

Key themes include:

- Climate change
- Limited availability of crop protection products
- Salinization of farmland
- Requirements from the Water Framework Directive
- The shift toward circular agriculture
- The protein and oil crop transition
- Use and availability of animal manure
- Growing societal expectations around biodiversity and landscape quality

These developments lead to one central question: *What will the arable farming of the future look like and how do today's decisions help us get there?*

Benefits

- Future-proof seed potato cultivation: Meeting stricter requirements for crop protection ,fertilization, and environmental impact — without compromising on quality or yield.
- Soil health as a foundation: Focused attention on soil life and structure ensures a strong crop start and reduces the risk of disease.
- Less dependent on chemicals: Mechanical weed control, resilient varieties, and precision technology help significantly reduce chemical inputs.
- Ready for stricter regulations: Proactively responding to upcoming legislation on fertilizers, crop protection, and water quality.
- Boosting biodiversity: Flower strips, strip cropping, and other measures support pollinators and natural pest control

AGRIFUTURE: Innovative crop strategies for seed potato cultivation

Additional information

Benefits

- More resilient to extreme weather: A robust crop rotation and healthy soil increase resilience to drought, excess rainfall, and temperature extremes.
- Innovation driving improvement: Precision farming and robotics enable more efficient use of labor and resources.
- An inspiration for fellow farmers: A regional example farm that inspires and supports others in transitioning toward circular agriculture.

AgriFuture aims to develop an arable farming system that meets ambitious future requirements for climate, environmental impact, and biodiversity. The approach is based on knowledge and technologies that are already available today, with room for further refinement through innovations such as robotics and precision farming.

Specific targets compared to current average arable farming practices:

- 30% reduction in mineral input
- 90% reduction in crop protection product use
- 90% reduction in chemical weed control
- 30% reduction in direct and indirect energy input
- 200% increase in above-ground biodiversity
- 100% increase in soil biodiversity
- 90% of mineral input sourced from regional nutrient cycles
- 1,500 kg CO_2/ha/year additional carbon sequestration

Challenges

It's challenging to make future-oriented decisions while relying on current knowledge, technology, and regulations. Innovations must be bold, but still applicable and workable for real farms in the region. Farmers, advisors, and experts often have different priorities, aligning them requires continuous dialogue and coordination. Shifting policies, market demands, and climate conditions create unpredictability, making long-term planning complex.

Resources

- Knowledge of the latest techniques and innovations
- Crop expertise within a renewed, future-oriented crop rotation system
- Active collaboration with various partners to expand knowledge and share experiences

Circular systems in action: cascade utilization and industrial symbiosis

In today's agricultural and industrial systems, a significant portion of biological resources is either wasted or underutilized. While green biomass like grass and clover is rich in valuable components—such as fibers, sugars, and nutrients—most of its potential remains untapped after initial processing for protein. Traditional value chains often stop at the primary product. However, sustainability and economic resilience require that we go further—transforming secondary outputs (like pulp and brown juice) into inputs for new value chains. This is known as **cascade utilization.**

At the same time, industrial decarbonization pathways, such as Power-to-X (PtX) technologies, are creating new resource flows like excess heat and biogenic CO_2. These flows, if coordinated wisely, can serve as inputs for agriculture and green refining. Unlocking this interconnected potential will require:

- New business models and partnerships across sectors
- Investment in R&D to mature low-TRL technologies
- Supportive policy and regulatory frameworks
- Regional planning to enable physical co-location and material exchange

Benefits

Full-value recovery: Green biomass contains much more than just protein. Press cake (pulp) and brown juice left after protein extraction can be further processed into valuable products for multiple sectors.

Climate-friendly production: These processes reduce agricultural waste and carbon emissions, while enabling local production of packaging, textiles, fuels, and building materials.

Industrial synergies: Residual heat, carbon, and process water from Power-to-X (PtX) systems can be reused in biorefineries, creating closed-loop, resource-efficient value chains.

Economic development: Cascade utilization and PtX symbiosis support the emergence of new green industries, jobs, and regional development—positioning northwest Jutland as a hub for climate-smart innovation

Circular systems in action: cascade utilization and industrial symbiosis

Additional information

The green biorefining process begins with protein extraction, but it doesn't end there. What remains—pulp and brown juice—has substantial commercial and environmental value:

- Pulp (pressed plant fiber):
  - Can replace wood fibers in products like cardboard, insulation, and bioplastics
  - Can be further refined into cellulose for high-end uses like textile production or packaging
  - Has the advantage of lower lignin content compared to wood, easing purification processes
- Brown Juice (sugar- and nutrient-rich liquid):
  - Used for precision fermentation to grow targeted microorganisms for food, feed, or pharma
  - Can be converted into ethanol or other biofuels
  - Offers potential as a biogas substrate or as part of organic fertilizer systems

Together, these streams can power new circular business models rooted in sustainability and zero-waste principles.

PtX technologies—such as hydrogen production from renewable electricity—produce valuable by-products like excess heat and CO_2, which can feed into green refining operations:

- Excess heat can dry protein pastes, evaporate brown juice, or power fermentation processes
- Process water from refining can be cleaned and reused in hydrogen production
- Biogenic CO_2 and leftover biomass can feed into biogas or biochar production

By co-locating facilities, industries can exchange heat, water, and nutrients—reducing costs, emissions, and resource loss. This model is particularly powerful in regions like northwest Jutland, where strong agricultural traditions, renewable energy capacity, and innovation leadership create ideal conditions for integrated green value chains.

Challenges

- Limited maturity of cascade-processing technologies
- Need for strategic co-location of industries (PtX and biorefining)
- Lack of standard frameworks for sharing residual flows across sectors

Resources

- Policy support and investment in infrastructure
- Industrial-scale R&D and tech development
- Agreements for resource sharing between facilities

Cultivating innovation - trans4num INSPIRE Hackathon highlights

The trans4num INSPIRE Hackathon 2024 fostered innovation and collaboration in sustainable nutrient management, integrating Nature-Based Solutions (NBS) with digital tools to strengthen research-practice connections and international cooperation. The trans4num INSPIRE Hackathon 2024 accelerated innovation in sustainable nutrient management by fostering collaboration between farmers, researchers, and technology experts. It provided a platform for developing and testing practical solutions, ensuring that NBS and digital tools could be effectively applied in real agricultural settings. The event helped bridge the gap between scientific research and practice, enabling participants to co-create scalable and impactful innovations.

Despite the proven benefits of NBS, their adoption in agriculture remains slow due to limited awareness, complexity, and a lack of decision-support tools. Farmers, researchers, and policymakers need practical, data-driven solutions to integrate NBS into real-world farming systems. Key outcomes included AI-driven geo spatial analysis, agent-based modeling, and interactive NBS toolkits, all aimed at improving nutrient efficiency, biodiversity, and ecosystem resilience. The hackathon also played a crucial role in strengthening international cooperation, particularly between Europe and China, by facilitating knowledge exchange and setting the stage for future joint initiatives in sustainable agriculture. Beyond generating innovative solutions, the hackathon empowered participants by expanding their skills and professional networks. It provided hands-on experience with cutting-edge technologies, encouraged interdisciplinary problem-solving, and raised awareness about the importance of NBS in modern farming. By combining technology, research, and stakeholder engagement, the event contributed to shaping policy, research, and practice, ensuring that sustainable nutrient management becomes a core element of future agricultural systems.

Cultivating innovation - trans4num INSPIRE Hackathon highlights

Additional information

The hackathon began with a *Call for Challenges*, inviting researchers and practitioners to define key problems related to nutrient efficiency, biodiversity, and ecosystem resilience. This was followed by a *Call for Participants*, attracting a diverse mix of students, researchers, and professionals. Throughout the Hacking Phase, teams collaborated with expert mentors, leveraging open data and technical support to refine their solutions.

The event concluded with a *Final Evaluation,* where a jury assessed projects based on innovation, impact, feasibility, and scalability. The winning solutions addressed critical agricultural challenges. The Gold-winning team developed an agent-based modelling tool to assess NBS adoption in different farming contexts, aiding policymakers and researchers. The Silver-winning team applied AI-driven geospatial analysis to enhance rural development and precision farming, improving land-use planning and nutrient management. The Bronze-winning team created an interactive NBS demonstration toolkit, bridging the gap between scientific knowledge and practical application through hands-on experiments. Other projects focused on cloud-free crop monitoring, high-precision meteorological forecasting, and regional nutrient balance modelling, all contributing to trans4num's goal of enhancing agricultural sustainability.

On the trans4num dedicated Hackathon page you will find more information about the challenges and the mentors, as well as the final reports from the trans4num INSPIRE Hackathon teams.

› trans4num INSPIRE Hackathon

Cut-and-carry green manure: opportunities for plant-based nutrient management in potato systems

Cut-and-carry green manure systems are increasingly promoted as plant-based alternatives to chemical fertilizers in nutrient management strategies. This study evaluates the impacts of such systems on seed potato yield, soil health, and nutrient cycling in Northern Netherlands. Despite short-term improvements in soil structure and microbial diversity, long-term results reveal challenges in maintaining nutrient availability for crops.

There is growing pressure to reduce chemical fertilizer use due to environmental risks and resource scarcity. Nature-based solutions (NBS), such as plant-based manures, can support more circular nutrient flows, especially where animal manure is unavailable. However, it remains unclear how complete substitution with green manure affects soil function and crop yield, especially under nutrient-deficient conditions. This long-term field trial tested a system relying entirely on cut- and carry-green manure and crop rotation. Results were compared to conventional systems using chemical or animal manure-based fertilization. We assessed soil nutrient profiles, microbial dynamics, and calculated soil health scores.

Cut-and-carry green manure systems can contribute to more circular and plant-based nutrient management, especially in areas where animal manure isn't available. In our field trials, applying clover silage improved soil structure early in the growing season and boosted microbial diversity. The system also showed potential for carbon and nitrogen fixation, which are important for building long-term soil fertility.

However, the full replacement of chemical fertilizer with plant-based inputs brought some challenges. Nutrients were not always available when the potato crop needed them most, and competition between soil microbes and plants likely reduced nutrient uptake. As a result, yields were lower and soil health declined by the end of the season.

Cut-and-carry green manure: opportunities for plant-based nutrient management i…

Additional information

Our research pilot explored whether a fully plant-based fertilization system could match or replace conventional methods in terms of soil health and crop yield. The trial was carried out on long-term organic seed potato fields in the north of the Netherlands (Munnikenzijl) and included four systems:

- A conventional system using chemical fertilizers (CF)
- An organic system with goat manure and cattle slurry (COF)
- A plant-based system using only cut-and-carry clover (POF)
- The same plant-based system with additional compost (POFC).

Over one year with two time points (before planting and just before harvest), we measured yield, soil nutrient availability, microbial activity, and soil structure. The plant-based systems performed well in some areas: they improved microbial diversity and showed higher potential for nitrogen fixation.

They also enhanced early soil aggregation. However, nutrient availability during crop growth was a challenge, especially for phosphorus. The full replacement of chemical or animal-based fertilizer resulted in lower potato yields and lower soil health scores after harvest. Compost helped improve outcomes slightly but didn't fully close the gap. These findings suggest that while cut-and-carry green manure can support nature-based nutrient strategies, they may not be sufficient on their own—especially in nutrient-poor soils.

Challenges

- Nutrient release didn't match crop demand, especially during the later growth stages
- Timing of application was difficult to optimize, as organic inputs decomposed quickly in early spring, releasing nutrients before the crop could use them
- Different potato varieties were used in conventional and organic systems, which is realistic for practice but complicates direct comparisons of outcomes

Resources

- Land for dedicated cut-and-carry green manure production
- Access to high-quality compost to balance nutrient supply
- Equipment to apply and incorporate organic material efficiently
- Soil and weather monitoring to better time applications

Fostering population growth of kestrel (Falco Tinnunculus) in agricultural areas

A decline in the population of many bird species has been observed (Eurostat 2020). A good opposite example is the common kestrel in the southern part of Hungary (Baranya-county), where the farmers,

nature conservation experts and the ornithologists protects the kestrel population with combined forces, for a decade now.

One of the major challenges for crop farmers(mostly for no-till, min till farmers) is the increasingly widespread common vole (microtus arvalis). In the latest years their presence was a deterring factor in many farmers yields. Due to the climatic changes, no tillage agriculture and the regulatory environment, their numbers skyrocketed, often leading to the formation of a gradation. (D. Roos, 2019). By cause of intensive agriculture, the number of field protecting tree strips is decreasing. That's affecting the kestrel population negatively since they don't build their own nests, mostly occupying nests built by different crow species.

The best solution that is also proved by many researches is to install nesting crates for the common kestrel. As mentioned before they aren't building their own nests and they are very exposed to the environmental changes (E. Baltag, 2014). Our solution is to provide artificial nests for them to nest successfully. According to the report of the Foundation on Nature Values of Baranya, after installing the kestrel boxes, there has been a rapid growth in the population indicating that the local problem was mainly caused by a lack of nesting sites. Another nature based solution regarding this topic is a biological rodent management. The kestrel is a natural predator to the common vole. The larger the kestrel population, the better they can control the vole population, which means farmers can use less rodenticide, which is essential for sustainable farming.

Fostering population growth of kestrel (Falco Tinnunculus) in agricultural areas

Additional information

- The biggest challenge is to get the different AKIS members to be open to working together, to listen to each other's perspectives and to develop a common plan of action.
- The willingness of the involved parties to cooperate is as important as a resource as it is as a challenge. Good communication between them is essential. In addition to these two very important resources, cooperation will also need funds to finance the project.

The benefits

This co-operation - started by the Foundation on Nature Values of Baranya (FNVB) - shows that different AKIS members, with different goals in mind (foundations, farmers, companies) can work together smoothly. It's a great example set by the parties involved. Crop farmers benefit greatly from the increase in kestrel populations for rodent control. It is a well-known fact, that kestrels can be a great help against various pests, for example the common vole. The consumption of breeding pairs and broods reduces the damage caused by the rodents. (FNVB, 2024). Another great asset of the birds is their role as natures indicators (Lederer 2020), and by monitoring them we can see that their annual population, and the success of the breeding season are indicative of the population trends of the common vole (FNVB, 2024).

From grass to value: refining green biomass for protein and nutrients

Grass refining turns green crops into high-value protein, feed, and bio-based materials. trans4num supports this climate-friendly approach to boost soil health, reduce emissions, and strengthen circular farming in Denmark and beyond.

Denmark's agricultural sector faces pressing environmental challenges—including nutrient surpluses, biodiversity loss, and oxygen depletion in inland waters. These issues are exacerbated by high levels of greenhouse gas emissions from conventional farming practices. To address these impacts while maintaining high food production, there's a growing need for regenerative agricultural systems that are both economically viable and ecologically sustainable.

This calls for a fundamental restructuring of how we grow food, use land, and manage nutrients. Green leafy crops such as grass, clover, Lucerne, and nettle represent a promising solution. These crops not only thrive in Danish conditions, but also:

- Provide some of the highest protein yields per hectare
- Require no pesticide use
- Help store carbon and reduce nutrient leaching when grown continuously on the same land

At the same time, the global demand for sustainable protein sources is increasing—making the case stronger for transitioning to nature-based, locally adaptable food and feed systems.

Benefits

Climate and Environmental Gains: Grass absorbs nutrients effectively and reduces nitrogen leaching. Long-term cultivation stores more carbon in the soil. Grass is pesticide-free, which supports soil microbial life and protects groundwater.

Biodiversity and Water Protection: Green leafy crops (including those often seen as weeds) help preserve water quality and biodiversity in inland ecosystems like lakes and streams.

Farm Productivity: Refining boosts the utility of farmland—protein is used for feed (poultry, pigs, cattle), while pulp and brown juice open additional value streams. Farmers gain more from the same land area.

From grass to value: refining green biomass for protein and nutrients

Additional information

What is Green Biorefining?

Green biorefineries work much like potato starch factories, using mechanical and thermal processes to separate plant components. Here's how it works:

› Leafy crops are pressed to extract green juice.

- This juice is heated (60–80°C) to precipitate protein.
- The resulting protein-rich paste is dried into a green powder (for animal feed) or further processed into a white protein fraction (for food).

What Happens to the Rest?

Brown juice: Contains sugars and bioactive substances. Potential uses include:

- Fermentation cultures
- Biogas production
- Natural fertilizers
- Medical and industrial applications

Pulp (press cake): Still rich in nutrients and fiber. It can be:

- Fed to cattle, horses, and other livestock
- Used for textiles, paper, or insulation
- Further processed for biogas or bio-based materials

Green refining becomes even more efficient when farmers and refineries work together. This ensures that:

- Crops are cultivated and harvested in sync with processing capacity
- Surplus biomass is redirected to livestock or alternative uses
- Nutrient flows are optimized across farming communities

This model of shared planning and logistics reflects the collaborative DNA of Danish agriculture, helping maximize both ecological and economic returns.

Grass-based cropping systems: transforming the Danish agricultural landscape

Replacing traditional feed crops with perennial grasses in intensively farmed regions can benefit both terrestrial and aquatic environments, increase biodiversity, and help mitigate GHG emissions. Advancing biorefinery production and supply chains could create incentives for farmers to shift their cropping rotations towards more grass-based systems. Poor ecological status of aquatic environments, low biodiversity, and loss of soil carbon are significant challenges associated with high-intensity agriculture. With agriculture covering about 62% of the landscape, the agricultural sector in Denmark is no exception. Cereals and maize account for 52% and 7% of the Danish cropping area, respectively, making the agricultural landscape dominated by monoculture feed crops with a relatively high environmental impact. As an alternative, perennial grasses, when managed properly, can improve nutrient use efficiency, enhance soil carbon storage, and reduce the negative impact of farming on biodiversity.

The substitution of grass on cereal and maize field scan yield a new source of protein through protein extraction from grass through the biorefinery. In the biorefinery grass is pressed producing a green juice and a fiber fraction. From the green juice, protein is extracted through heating or steaming and can be fed directly to monogastric animals - thereby replacing the less sustainable soya feed. The fiber fraction can be fed to ruminants (e.g. cattle) or distributed to the biogas plant. In addition, the biogas plant also

receives manure etc. from the field, and the energy produced here can be transferred to run the biorefinery. The biogas remnants including potentially produced biochar finally is recycled back to the local fields as fertilizer and/or to promote carbon storage in the soil, thereby contributing to circularity of the system.

Grass-based cropping systems: transforming the Danish agricultural landscape

Additional information

Aarhus University is investigating the benefits of incorporating more perennial grasses into crop rotations, focusing on both production-specific aspects (biomass yield, protein content, etc.) and environmental factors within a landscape context (nutrient leaching, biodiversity, and climate).

The success of the landscape transformation towards increased grass cultivation depends both on knowledge on how benefits of the grass varies across the landscape and on active and positive engagement of stakeholders. Therefore, our research integrates various elements of landscape scale effects of the grass and stakeholder involvement to gain insight into their perspectives and to disseminate knowledge about the benefits of adopting this production practice.

In Denmark farmers are regulated based on - amongst others - the N retention map. This map is specific for Denmark and depicts the geographically varying sensitivity of how much N is retained in the soil before it reaches the recipient – the fjord. Hence, there is a spatially varying effect of how effective the grass is as a solution. From a farmer's perspective, this can facilitate discussion and potentially increased collaboration between actors of the landscape.

Challenges

- Economic and financial barriers, e.g., substantial investments and market uncertainties
- Supply chain infrastructure gaps and fixed processing capacity requires significant coordination
- Farmer resistance, e.g. due to risk aversion and lack of incentives and information
- Lack of policies and regulatory schemes to effectively support establishment
- Technological gaps in the supply and production chain e.g. side stream valorisation
- Environmental variability – difference in mitigation potential across the landscape

Green fertilizers: Lucerne and clover pellets for winter wheat

There is a growing need for research into alternative fertilization methods in grain cultivation. Conventional farming typically uses a combination of synthetic fertilizer and a second application of slurry. In organic farming, fully animal-based fertilizers are more commonly used. The challenges differ between the two systems. Organic farming already relies largely on circular fertilizers, but the availability of animal manure is limited, creating a demand for alternative sources. In conventional farming, linear (non-renewable) fertilizers are still widely used, accounting for about 50% of total fertilizer input. The key challenge here is reducing dependence on these inputs. Fertilizer price shave risen sharply in recent years, and concerns about nutrient leaching into surface water are becoming increasingly urgent. A potential solution for both systems could be increased use of plant-based fertilizers, such as alfalfa or grass pellets.

The use of plant-based fertilizers offers a major opportunity to reduce chemical fertilizer use in conventional farming. Additionally, it can help lower the use of animal manure in both conventional and organic grain cultivation. By introducing this third fertilization option, farmers become less dependent on synthetic and/or animal-based fertilizers. The use of more natural products is also expected to improve soil biodiversity, which in turn supports better soil health.

Grain farming often operates on tight margins, so rising fertilizer costs can have a significant impact on profitability. At the same time, the Netherlands faces a pressing challenge to improve water quality, an issue in which the agricultural sector plays a key role. Regulations on fertilizer use are becoming increasingly strict. The need to maintain yields while also improving water quality is urgent. Using plant-based fertilizers to help prevent nutrient leaching is a practical and forward-looking solution that fits well within the operations of many farms.

Green fertilizers: Lucerne and clover pellets for winter wheat

Additional information

We are testing whether the standard fertilization in both organic and conventional winter wheat cultivation can be fully or partially replaced by alfalfa and/or grass pellets. We are examining different application rates and timings. Soil samples are taken from the fields before and after the growing season to measure how much nitrogen and other nutrients remain in the soil. Throughout the season, crop development is monitored, focusing on plant growth, common diseases, ripening, and lodging. At the end of the season, yield and grain quality are assessed, including moisture content, protein level, Zeleny index, hectoliter weight, and starch content. The pellets used in the trials have been analyzed beforehand for their nutrient composition, which determines the appropriate application rate.

Each year, the different treatments are compared. After four years of research, we aim to provide a well-founded recommendation on the advantages and disadvantages of using plant-based pellets compared to current standard fertilization practices in both organic and conventional winter wheat farming.

Challenges

- Evaluating how Lucerne and grass pellets perform compared to conventional fertilizers in terms of yield and nutrient availability
- Reducing reliance on synthetic fertilizers
- Identifying the tangible agronomic benefits of using Lucerne and grass pellets on different soil types and crop systems
- Understanding the residual effects of Lucerne and grass pellets on subsequent crops, including cover crops and main crops
- Assessing whether plant-based fertilizers contribute to increased weed pressure in the field
- Determining the impact of plant-based fertilizers like grass-clover on soil biological activity and soil health

Resources

- Sufficient availability of plant-based alfalfa and/or grass pellets

- Possibility to apply the pellets early in the season onto the crop
- Knowledge of soil nutrient levels through soil sampling, in order to determine the correct fertilization dosage.

Look into the soil to understand the benefits of NBS for soil

Soil profile demonstrations are vital because soil remains a "black box" for many farmers. While the benefits of Nature-Based Solutions (NBS) are real, they often lie hidden below the surface. By analyzing soil profiles, we make these benefits visible—providing farmers with clear, tangible proof that sustainable practices improve soil health and fertility. This hands-on approach shows how different management techniques affect root growth, microbial activity, and soil structure. Farmers often judge soil by surface signs, which can be misleading. Digging deeper reveals the true impact of practices, helping them see the changes beneath their feet. Soil profile demonstrations turn abstract science into visible, practical knowledge. By making the invisible visible, we empower farmers to make better decisions that support long-term sustainability.

Empirical understanding is key to changing farming practices. Soil profile demonstrations offer visual proof of improvements like better structure, more organic matter, and higher water retention. Farmers see how cover crops, reduced tillage, and manure improve soil health—benefits often hidden from the surface. By revealing real results, demonstrations bridge the gap between science and practice, building trust in NBS. Farmers observe changes in porosity, root growth, and biological activity, strengthening the link between practices and soil quality. This boosts confidence in adopting and maintaining sustainable methods. Soil profiles also support peer learning, encouraging collaboration and shared knowledge. When farmers can see the long-term value of NBS, they’re more likely to make informed choices that support soil, yield, and resilience—advancing the shift to regenerative agriculture.

Look into the soil to understand the benefits of NBS for soil

Additional information

As part of a trans4num event, we conducted soil profile investigations to reveal variations within fields. By digging soil pits, we uncovered differences in composition—such as gravel layers in one area and rich, humus-rich topsoil in another—highlighting the importance of site-specific soil management. These hands-on demonstrations helped farmers directly observe the impact of Nature-Based Solutions (NBS) on soil health. Participants saw how sustainable practices affect root growth, soil stability, and water retention. This visual, tactile experience reinforced their understanding of how soil evolves under NBS and boosted confidence in applying regenerative practices. By linking soil characteristics to past management, farmers could better tailor their strategies for improved outcomes. Trans4num events serve as a platform for experiential learning, turning scientific knowledge into practical insight. These shared experiences strengthen peer learning, motivate sustainable action, and support the wider adoption of site-adapted regenerative agriculture.

Challenges

Implementing soil profile demonstrations can be difficult due to weather conditions like heavy rain or drought, which hinder accurate analysis. Timing is crucial, as farmers are busy during peak seasons.

Engagement is also a challenge, requiring strong communication and clear evidence of benefits to gain farmers' interest.

Resources

Successful implementation requires good planning to ensure the right timing and location. Strong networks with farmers, advisors, and agronomists support knowledge-sharing. Expertise and proper equipment are essential, as soil scientists help interpret results and provide valuable recommendations for farmers.

Monitoring nature: remote sensing as a key enabler of nature-based solutions

Nature-based solutions (NBS) aim to address societal and environmental challenges through the sustainable use of nature. However, their design and implementation require robust, continuous environmental data to guide planning and assess effectiveness. Traditional field-based monitoring is often too costly, time-consuming, or spatially limited to provide the required information at scale. Remote sensing bridges this gap by offering consistent, spatially explicit, and regularly updated environmental data. It supports the early identification of priority intervention areas, baseline assessments, and long-term impact monitoring. In a changing climate, where adaptive management is crucial, these capabilities are essential to the resilience and success of NBS.

Remote sensing supports NBS implementation in multiple strategic ways:

- **Scalability** – Satellite data enables consistent monitoring across cities, regions, or countries, helping planners prioritize based on ecosystem trends.
- **Repeatability** – Frequent data acquisition supports tracking seasonal dynamics, vegetation cycles, and ecological responses to NBS.
- **Cost-efficiency** – Open-access platforms like Copernicus (Sentinel) and Landsat lower monitoring costs and expand stakeholder access.
- **Integration potential** – Combining remote sensing with field surveys, IoT, or modeling improves multi-source environmental assessment.
- **Transparency** – Public data fosters accountability and trust through visual, data-driven reporting.
- **Indicator tracking** – Supports monitoring of indicators like NDVI, land surface temperature, water availability, and urban heat island effects.
- **Climate resilience** – Time-series analysis informs adaptive strategies by identifying long-term environmental trends.
- **Risk assessment** – Enables early detection of stressors like drought, flooding, or degradation, supporting timely NBS responses.

Monitoring nature: remote sensing as a key enabler of nature-based solutions

Additional information

Within trans4num, a dedicated Nature-Based Solutions (NBS) site in Hungary demonstrates how remote sensing supports sustainable land management. The site applies drone monitoring and GIS to track land cover, vegetation health, and water dynamics, enabling adaptive management and long-term impact assessment. Drones provide high-resolution data and flexibility, complementing satellites by

filling spatial and temporal gaps. The approach emphasizes accessibility using open tools like QGIS and Google Earth Engine, and low-cost drone tech to support uptake by small municipalities or civil groups. Capacity-building is central, with trainings and workshops enabling stakeholders to collect, process, and interpret spatial data. The NBS site serves as a practical, scalable model of how geospatial tools and collaboration can advance effective and inclusive nature-based solutions.

Challenges

- Expert knowledge is required to interpret remote sensing data
- Cloud cover limits the usability of optical satellite imagery
- Technical and financial barriers hinder small stakeholders' access
- Data integration issues affect consistency across different sources
- Institutional gaps and regulations can delay effective implementation

Resources

- Open or commercial satellite imagery for regular environmental monitoring
- GIS and image processing software like QGIS or GEE
- Trained personnel with expertise in remote sensing and analysis
- Sufficient computing infrastructure for data storage and processing
- Institutional support to integrate results into decision-making processes

Nature-Based Solutions for insect pest management

Traditional use of synthetic insecticides poses risks to both agriculture and food systems. They can harm human health through exposure or contaminated food, and pests are developing resistance, reducing their effectiveness. In oilseed rape, the cabbage stem flea beetle (CSFB) has become a major threat, especially in the UK and northern Europe. Since neonicotinoids were withdrawn, farmers rely on pyrethroids, yet resistance is now widespread. Reducing synthetic insecticide use must be balanced with effective pest control and crop protection, aligning with the One Health approach. EU policy, including Directive 2009/128/EC, promotes sustainable pesticide use and encourages farmers to adopt integrated pest management (IPM) strategies that are more resilient and environmentally sound.

Implementing regenerative practices can enhance crop resilience to pests, but it’s essential to anticipate trade-offs. Practices like reduced tillage, habitat creation, crop diversification, and organic amendments foster a farm ecosystem that works with nature. These measures can strengthen crops, promote beneficial insects, and improve pest tolerance. However, leaving residues on the soil surface may increase slug pressure.

Healthier soils build stronger plants.

Regenerative agriculture improves soil structure and fertility through compost, cover crops, and minimal disturbance. Healthy soils support robust plant growth, making crops less attractive to pests.

Rotations break pest cycles.

Many pests target specific crops. Rotating crops interrupts pest life cycles and naturally reduces their

populations.

Beneficial insects reduce pest pressure.
Parasitoids and other allies thrive in no-till systems, where they overwinter in the soil and help control pests.

Lower reliance on costly inputs.
Reducing pesticide use cuts costs and protects beneficial insects.

Regenerative pest management leads to fewer outbreaks, stronger crops, and a more resilient farm system.

Nature-Based Solutions for insect pest management

Additional information

The Rothamsted Research Large-Scale Rotation Experiment (LSRE) is testing multiple Nature-Based Solution (NBS) interventions, such as crop rotations, diversified cropping, minimal/zero tillage, and organic amendments, applied in different combinations to assess their impact on crop protection and resilience. A key focus is the natural suppression of pests. LSRE monitors the synergies and trade-offs of these approaches, as well as their effects on crop yield, establishment, and condition. Pest dynamics require long-term monitoring. Since LSRE began, reduced tillage systems have seen increased populations of parasitoids that target oilseed rape pests. Other Rothamsted trials show that intercropping reduces pollen beetle damage, while companion planting (e.g., using turnip rape as a trap crop alongside oilseed rape) helps divert pests. LSRE is studying these interactions across contrasting systems. Off-crop habitat management also plays a role, flower-rich margins or in-field strips of companion crops support biocontrol and biodiversity, reducing pest larvae and highlighting the benefits of plant diversification.

Challenges

- Direct drilling is required if using a minimum or zero till approach. This can, over time cause compaction of soil.
- Zero/Min tillage not always appropriate for all soil types.
- Introducing companion plants can be costly due to seed costs and require additional costs for implementation.
- Companion plants may counteract the efforts of one pest but could result in attracting other pests (e.g., clover is a deterrent for CSFB but attracts slugs).

Resources

- A direct drill
- A plan for crop rotations and understanding of what companion plants will work with the chosen crops in relation to pests.

- Knowledge to manage the outcomes of diverting pest attention.

Plant-based fertilizer and natural crop protection in seed potatoes

Viruses are a serious threat to seed potato cultivation, often causing deformities and yield loss in affected plants. Symptoms include leafroll and mosaic patterns on the leaves. To identify and remove infected plants, seed potato growers carry out field inspections throughout the growing season. If too many infected plants are found, the crop may be rejected by the certification authority (Dutch: NAK).

These viruses are primarily spread by aphids, which transmit the virus by piercing the plant. To prevent this, farmers spray insecticides and mineral oil onto the crops. However, an increasing number of these products have been banned in recent years, making it more difficult to protect the plants effectively. As a result, alternative methods are being explored, such as covering the potato crop with straw to reduce aphid pressure. In this study, not only straw but also fresh grass and grass-clover were used. This choice was made because straw requires nitrogen to decompose. The aim of the study is to find out whether grass and grass-clover have the same effect on aphid populations as straw.

Reducing the use of synthetic fertilizers is a key priority for seed potato growers. One specific area for improvement is the additional application of mineral nitrogen used to help break down straw. When straw is applied to reduce aphid pressure in the field, it competes with the potato plant for nitrogen, as straw decomposition consumes nitrogen from the soil. This study explores whether grass-clover and/or fresh grass could serve as effective alternatives to straw. These options are evaluated alongside the traditional method of using mineral oil. The research also investigates whether intercropping different types of green manures between the potato ridges can offer a natural solution to virus problems. The green manure begins growing earlier than the potato plant, so aphids may settle on the green manure instead, potentially reducing the risk of virus transmission to the crops.

Plant-based fertilizer and natural crop protection in seed potatoes

Additional information

The research begins by exploring why certain practices are used in Dutch seed potato cultivation, and what drives growers to make these choices. These decisions are discussed with both farmers and advisors. The next challenge is to determine whether the same goals can be achieved using alternative methods, while also reducing the input of minerals. This involves raising awareness among growers about the importance of limiting mineral use to protect water quality. By monitoring nitrogen uptake by the crop at multiple points during the growing season, we gain a clearer understanding of the process and of the impact of inter-row green manures or straw/grass covers on the potato crop. With these insights, growers can adjust their management throughout the season, helping to minimize potential yield losses due to reduced mineral input.

Challenges

- Minimizing pesticide dependency: Achieving a significant reduction in pesticide use, including the near elimination of aphid control agents and oils for virus prevention.
- Reducing fertilizer inputs: Lower reliance on chemical fertilizers while maintaining crop performance.

- Restoring productivity: Recovery of previously lost yields and enhanced farm resilience and operational efficiency.
- Boosting biodiversity: Decreased chemical inputs contribute to improved biodiversity and reduced ecological impact during cultivation.
- Enhancing water quality: Reduced leaching of agrochemicals leads to better water quality at the regional scale.

Resources

- Nitrogen sampling at the beginning and end of the growing season.
- Crop development assessments at several points during the season.
- Evaluation of plant differences and stem counts to determine the impact of each treatment.
- Yield measurement and size grading per plot.
- Virus monitoring during the season and through post-harvest tuber inspections.

Planty Organic: Long-term crop rotation with plant-based nutrition

Planty Organic is a long-term farming experiment that began in 2012 at the SPNA experimental farm in Kollumerwaard. It focuses on organic crop production using only plant-based inputs. Instead of animal manure or synthetic fertilizers, the system uses legumes, cover crops, green manures, and "cut-and-carry" plant material to feed the soil. The main crops include potatoes, pumpkins, grains, and grass-clover.

Planty Organic began with a question from a group of organic arable farmers in the Northern clay region of the Netherlands: How can we make better use of nitrogen in organic farming—and improve efficiency without relying on animal manure or synthetic fertilizers? That question sparked the start of the Planty Organic experiment in 2012. The research uses a crop plan typical for the region—potatoes, pumpkins, carrots, grains, and grass-clover—supported by green manures. What makes it unique is its commitment to plant-based inputs only. For the first 10 years, no minerals or manure were added. Instead, grass-clover was harvested and returned to the field as fertilizer—a method known as “cut and carry.” After this initial period, compost and bokashi were introduced into the system. However, even today, no animal manure or synthetic fertilizers are used—staying true to the plant-based approach that inspired the project.

One of the main challenges with plant-based fertilization is the mismatch between **nitrogen supply and crop demand over time**. This imbalance can lead to significantly lower yields for certain crops. We currently lack detailed knowledge about the optimal timing and methods for applying plant-based fertilizers. Understanding how to synchronize nutrient release with crop needs is crucial for improving performance and reliability in fully plant-based systems.

Planty Organic: Long-term crop rotation with plant-based nutrition

Additional information

Within the trans4num project, we are exploring how plant-based fertilization can shape the future of sustainable farming. Several ongoing experiments are helping us better understand its impact:

- *Microbial research with Wageningen University* - Wageningen University is studying our fields to compare the microbiological effects of plant-based nutrition with those of conventional organic farming systems.
- *On-farm implementation with over 20 farmers* - Since 2022, more than 20 arable farmers have started applying our knowledge to improve their use of cover crops—supported by one of the Netherlands' largest farmer cooperatives. Their advisors play a key role in sharing practical results.
- *Pioneering fully plant-based farming* **-** A small number of organic farmers have now fully transitioned to plant-based nutrition. At the moment, this is the only known method that enables 100% vegan-certified food production.
- *Farm of the Future* **-** We've launched a new long-term field experiment called The Farm of the Future, where we apply this knowledge in a conventional arable farming system.

The benefits

No Animal By-Products: Plant-based fertilizers contain no liquid manure, bone meal, or blood meal. This greatly reduces the risk of contamination with pathogens, hormones, or antibiotics.

Healthier Soil and More Biodiversity: These fertilizers feed soil life by providing organic matter that supports beneficial microbes. Materials like vegetable compost and cover crops help build a living, resilient soil with better water retention and natural disease resistance.

Less Dependence on Livestock: Using plants and organic waste as fertilizer reduces reliance on animal manure, an important advantage in regions like the Netherlands, where organic manure is costly.

Lower Risk of Nutrient Leaching: Unlike synthetic fertilizers or liquid manure, many plant-based fertilizers release nutrients slowly, allowing crops to absorb them over time and reducing the risk of groundwater contamination.

Regional scale satellite monitoring

Satellite monitoring enables a cost effective solution to understanding the spatial variation throughout a large NBS site. It provides an effective way of monitoring effects after applying a NBS, and enables better and more precise understanding of the potential of applying a NBS on a regional scale.

In the trans4num Decision Support Tool, we focus on the effects of introducing NBS across an entire region. In the Danish site this region contains more than 40.000 fields. Here a primary focus is on the spatial effect of the NBS, where the effect of decisions is highly affected by aspatial component. This requires deep understanding of the spatial variation of the arable land in the region. Satellite monitoring provides a crucial input to this understanding, and can help in measuring the actual effect of implementing a NBS across the region. In order to understand the context of a large region, it is key to know the crops on individual fields on every growth season, an application where satellite monitoring is a very efficient tool to provide insights on the most important crops.

Manual data collection, like soil sampling, at individual fields is at best sparse, and with varying degree of details across farms. Data collected withdrones, enables very precise high resolution data, however the cost of collecting data, makes it very hard to obtain for large regions, especially in atemporal context, where data has to be fetched throughout the growth seasons. Remote sensing makes the trade-off whereprecision and spatial resolution is sacrificed for high temporal resolution, and complete spatial coverage. This makes a perfect match for the regional scale at which the trans4num Decision Support Tool operates. Here the focus is not on optimization within a specific field or farm, but at a regional scale. Hence the high resolution from more precise sources like UAV monitoring is of no to little benefit.

Regional scale satellite monitoring

Additional information

Aarhus University and Cordulus provides a satellite monitoring pipeline targeted towards the regional scale NBS sites in the trans4num project. The data is directly targeted towards the NBS decision support tool being developed in the project. Many of the existing work and tools for satellite monitoring are focused on the monitoring of field or farm level variation of fields. In trans4num the focus has been shifted towards monitoring of large regions, which introduces a requirement for a very effective pipeline and processing chain, but which in turn also enables a smaller focus on individual details in the collected data. The satellite imagery works as a key input to the Decision Support Tool, for it to function effectively. The Decision Support Tool, is capable of describing spatial variation based on tabular values, manually collected field data and low resolution nitrogen leaching maps, however a more detailed spatial effect of introducing NBS solutions can be extracted through the use of satellite imagery.

Challenges

- The access to large quantities of ground truth data is required in order to generate effective monitoring algorithms. This is due to the fact that we monitor large regions, and have large quantities of low resolution input data available, but data driven models also require a lot of targets in order to generalize.
- The noise in satellite imagery primarily from clouds introduce significant challenges for automated analysis.

The remote sensing satellite data enables time series monitoring of crop health at the scale, and provides important inputs on the spatial variation in growth of individual crops, throughout several growth seasons, providing detailed insights throughout the case areas.

Small actions in light of transformation

Transforming agricultural practices—or entire farming systems—may seem ambitious or even utopian. However, the trans4num approach promotes a stepwise, reflective and iterative process to integrate nature-based solutions(NBS). This method benefits individual farm sites and cumulatively contributes to a broader shift from linear to circular nutrient management.

Intensive farming systems are increasingly challenged by persistent environmental issues such as nutrient runoff, soil degradation, and declining biodiversity. Traditional nutrient management practices

often fail to address these challenges adequately, resulting insignificant negative ecological impacts that extend beyond the farm. By integrating NBS such as cover crops, riparian buffer strips, and agroforestry, farmers have the opportunity to recycle nutrients effectively, improve soil fertility, and mitigate environmental damage. A key challenge is that no single solution can be universally applied; each farm has unique characteristics such as soil type, climate, and existing management practices. A range of locally adapted strategies is necessary to generate meaningful, cumulative changes that pave the way for a transformation from linear to circular nutrient management. Moreover, there is a critical need for a stepwise and reflective approach. Each intervention must be evaluated to ensure it contributes not only to local improvements but also to the transformation toward circular nutrient management. This methodical progression helps prevent missteps and ensures that the innovations adopted are both effective and sustainable over the long term.

Adopting a stepwise approach in nutrient management offers several significant benefits for both individual farm operations and the broader agricultural community. It creates a dynamic network among farmers, advisors, and other stakeholders who share a common interest in sustainable practices.

Small actions in light of transformation

Additional information

A Gradual Yet Transformative Approach

The trans4num project embodies an incremental yet transformative approach to rethinking nutrient management. Our strategy is built on the recognition that agricultural systems are inherently complex and that achieving radical change requires a gradual, well-monitored process. Rather than pursuing an abrupt overhaul, trans4num promotes a series of deliberate, small-scale innovations that cumulatively drive circular nutrient management transformation.

Local Implementation & Empirical Trial Sites

At the heart of the trans4num approach is the implementation of NBS at trial sites. These sites serve as living laboratories where local knowledge and innovative practices are harnessed to create tailored solutions that meet specific environmental and operational needs. By starting at a manageable scale, farmers can experiment with NBS such as cover crops or constructed wetlands, gather empirical data, and adjust practices accordingly before wider adoption.

Stepwise Adaptation & Scalable Innovation

Innovation in trans4num is built on incremental steps—each designed as part of a larger system shift toward circular nutrient management. Small transitions, from initial trials to broader implementation, build momentum by showing real-world benefits. The framework reflects on short-term barriers (like resource limits or knowledge gaps) and deeper lock-ins (such as entrenched practices or weak governance). This dynamic, stepwise approach helps ensure lasting impact. As local solutions prove effective, they can be adapted and scaled to other regions, multiplying their influence. By combining adaptability with a long-term vision, trans4num supports both immediate improvements and deeper, structural transformation in nutrient management.

Challenges

- Address lock-ins and reflect to drive real change in nutrient management.

Resources

- Build networks, share knowledge, and support NBS to scale across farming systems

Soil carbon stewardship and Nature-based solutions: Managing Soil organic carbon
Soil organic matter (SOM) is ~50% carbon; the rest includes nutrients like N, P, S, O, and H that support microbial life. Microbial activity enhances soil structure, water retention, aeration, and root growth, making SOM a vital nutrient reservoir. Most carbon is stored in soils, so soil organic carbon (SOC) plays a key role in climate regulation. Yet, SOC is easily lost through conventional farming, which disrupts soil structure and hinders carbon replacement. Effective land management is essential to make soils reliable carbon sinks. However, knowledge gaps remain about which practices, or combinations, best enhance SOC. Promising options include reduced tillage, perennial crops, cover cropping, managed grazing, manure or compost application, and residue retention. The impact of any NBS depends on how it's combined with others. Rothamsted's LSRE tests systems integrating compost, cover crops, reduced tillage, and perennials.

Even small increases in SOM and SOC benefit soil health, boosting water and nutrient use efficiency, soil structure, and biodiversity (e.g. earthworms). In the global north, carbon-rich soils must be responsibly managed. Globally, soils (mainly agricultural) could sequester over a billion additional tons of carbon per year. Nature-Based Solutions (NBS), like those tested in Rothamsted's LSRE, support SOC and SOM through practices such as reduced tillage, residue retention, compost and manure application, and leys in crop rotations. These practices enhance microbial activity and nutrient cycling, contributing to long-term soil and planetary health. NBS create favorable conditions for sustaining soil function and resilience. SOM is typically measured via Loss on Ignition (burning off organic matter), while SOC is more precisely assessed using the Dumas method (dry combustion), which quantifies CO_2 released by heating soil in oxygen-rich air.

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Additional information

The Rothamsted Research Large-Scale Rotation Experiment (LSRE) tests multiple Nature-Based Solutions (NBS), such as crop rotations, diversified cropping, minimal/zero tillage, and organic amendments, applied in combinations to assess their effects on soil properties, especially SOC and SOM. LSRE monitors synergies, trade-offs, crop yields, and fertilizer use efficiency. SOC must be measured over time, as weather causes seasonal fluctuations. While all treatments showed short-term SOC decreases, long-term results highlight the consistent benefits of NBS, confirming the value of long-term trials. SOC often rises in rotation phases with NBS input (e.g. compost) and falls in others; thus, benefits are assessed at the full-system level. After six years, the top five systems for SOC all combined compost with reduced tillage, even on sandy soils with limited storage capacity. Larger impacts are

expected at the clay soil LSRE site. Managing SOC requires strategies like reduced tillage, cover crops, livestock integration, compost, and residue retention—all of which enhance SOM, soil structure, and ecosystem services like water retention and reduced input loss.

Challenges

- LSRE does not include livestock integration, so not representative of a mixed system.
- Challenges in removing cover crops and perennial lays without tillage.
- Over-reliance onglysophate.
- Extreme weather and establishing cover crops in time for growing season.

Resources

- Direct drilling machinery appropriate to soil type.
- Access to livestock manure and/or livestock plus livestock infrastructure.
- Access to green compost.
- Appropriate varieties for diversified cropping rotations.

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