Practice abstracts for farmers, 1st batch

30 September 2025

Deliverable D5.3 (version 1.1)

Funded by
the European Union

Project name	**Transformation for sustainable nutrient supply and management**
Project acronym	**trans4num**
Project ID	101081847
Project duration	December 2022 – November 2026
Project Coordinator	University of Hohenheim (UHOH)
Project website	https://trans4num.eu/
Work package	Work package 5
Work package leader	Highclere Consulting (HCC)
Deliverable number and title	D5.3 Practice abstracts for farmers, 1st batch
Authors	Elena Ion, Mark Redman, Alina Alexa. Special recognition goes to the trans4num partners who contributed by writing the Practice Abstracts.
Version	1.0
Dissemination level	Public

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1. Introduction

1.1 Purpose of the deliverable

The purpose of the deliverable D5.3 is to provide the first batch of 15 practice abstracts tailored specifically 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, test 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 translation into the project languages and 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)

The PAs are enhanced beyond the EIP-AGRI common format to support greater impact, including design elements, visuals and multilingual accessibility.

1.3 Target audience: farmers and advisors

The primary target audience for these practice abstracts include farmers and farm advisors who are directly involved in land management and the implementation of sustainable agricultural practices. These end-users are key actors in applying nature-based solutions at field level.

Secondary audiences include:

- Agricultural cooperatives and producer groups

- Advisory services and extension officers
- Policy implementers at local and regional levels
- Environmental NGOs and civil society organisations
- Education and training institutions involved in agricultural knowledge transfer

These abstracts are written in accessible language to ensure that practical knowledge and tested solutions can be understood and applied by practitioners across diverse European contexts. To promote inclusivity and broader uptake, the abstracts will be translated into the working languages of the project: Danish, Dutch, German and Hungarian (based on the request of the partners).

1.4 Format alignment with EIP-AGRI requirements

HCC has reviewed Horizon Europe's submission guidelines for practice abstracts within the EIP-Agri database on the EU CAP Network platform. Following this, an account was established on the Horizon Project Dashboard, where a draft project description was created and WP5 team provided partners with templates and training to ensure full alignment with the new EIP-Agri format.

2. Methodology

2.1 Overview of the preparation and coordination process

During the General Assembly in June 2024, the concept of practice abstracts was introduced to project partners, emphasizing the contractual requirements and identifying potential topics. To facilitate contributions, an online collection tool was shared with partners, allowing them to submit topics and nominate authors for the initial 15 abstracts. To support partners, HCC circulated guidance documents outlining the expected structure and content of practice abstracts. On 28 November 2024, an online meeting was held to clarify the process, define key steps, and agree on submission deadlines. In January 2025, official project templates were distributed to authors, accompanied by an additional online session to review the template and reinforce deadlines.

Figure 1 Screengrab from the excel file circulated to partners for topic proposition

trans4num Practice Abstracts

Add your topic in this table by 20th December 2024

Nr. Crt	Partner	Author	Topic What is the solution that you want to share?
1	SZE	V. Vona - I. Kulmány - Z. Fűzfa - A. Vér	Soil evaluation and demonstration
2	RRES	Moore, Tooke, Storkey	Soil carbon and soil health
3	RRES	TBC	Pests
4	RRES	TBC	Weeds
5	RRES	TBC	Diseases
6	SPNA	M. Dilling	Plant-based fertilizer and natural crop protection
7	SPNA	M. Dilling	Lucerne and grass-clover pellets for fertilising conventional and organic winter wheat
8	SPNA	M. Dilling	AgriFuture – Innovative crop strategies for seed potato cultivation
9	SPNA	M. Dilling	AgriFuture: Innovation in crop rotations, soil health, and cultivation strategies on heavy
10	KLIMAFONDEN	Pia Strunge Folkmann	Green Refining - what and why
11	P4ALL	Marketa Kollerova, Tomas Mildorf	Cultivating innovation: trans4num hackathon highlights
12	CORDULUS	Morten Birk	Regional scale satellite monitoring.
13	UHOH	Friederike Selensky, Andrea Knierim tbc.	Transformation pathways towards circular nutrient management
14	SZE	A. Vér - T. Szikszai	Fostering population growth of kestrel (Falco tinnunculus) in agricultural areas.
15	SZE	V. Vona - I. Kulmány - Z. Fűzfa - A. Vér	Monitoring Nature: Remote Sensing as a Key Enabler of Nature-Based Solutions
16	KLIMAFONDEN		Cascade utilization
17	KLIMAFONDEN		From grass to protein
18	KLIMAFONDEN		Symbiosis with power-to-x
19	WU	Paula Harkes	Cut-and-carry green manure
20	AU	Mette V. Odgaard - Anton Rasmussen - Morten E	Grass-Based Cropping Systems: Transforming the Danish Agricultural Landscape

2.2 Timeline and workflow

To support the submission of Deliverable D5.3, all project partners were invited to propose topics based on the work conducted to date within the trans4num (Europe) project. Following topic selection, the WP5 team developed and distributed dedicated templates for the preparation of practice abstracts to those partners who expressed interest in contributing.

For this first batch of 15 practice abstracts, a slightly adapted approach was taken to facilitate partner engagement and reduce workload. Rather than developing the basic EIP-Agri format first and enhancing it later, WP5 introduced the trans4num factsheet from the outset. These factsheets are enhanced practice abstracts designed to follow the same core structure (addressing the *Why, What, and How*), while offering additional content and visual appeal, such as images, diagrams, and practical insights.

Each factsheet presents a field-tested solution or experience, directly addressing a real challenge or need faced by farmers or advisors. They also outline the resources required and reflect on any challenges encountered during implementation. To streamline the process, the templates were made available via editable Canva files, and partners were given a three-month period to develop their contributions.

Following the three-month drafting period, Highclere Consulting (HCC) initiated the review of the submitted Canva files. The review focused on ensuring design consistency across all factsheets, correcting typographical errors, refining text layout, and improving the logical flow of content. Once finalised, the files were downloaded and prepared for upload to Zenodo, where each factsheet was assigned a Digital Object Identifier (DOI). These DOIs will be used to establish cross-links between the enhanced factsheets and the corresponding entries in the EIP-Agri database, thereby strengthening the visibility and traceability of trans4num's practical outputs.

3. Overview of the Practice Abstracts

Initially, a total of 22 topics were proposed for the development of practice abstracts based on activities carried out within trans4num. However, by the internal submission deadline for the trans4num factsheets, 17 factsheets were finalised and included in this first batch. The remaining five trans4num factsheets will be submitted as part of the second batch in Deliverable D5.7, scheduled for Month 44.

The table below provides an overview of the 17 practice abstracts submitted as part of Deliverable D5.3. It includes the responsible partner, the topic/title of the abstract, and a set of key words describing the focus and thematic relevance of each contribution.

Table 1 Overview of submitted Practice Abstracts

Partner	Title	Main topic	Location	Keywords	DOI
SPNA	AgriFuture: Innovating Crop Rotations & Soil Health on Clay Soils	Sustainable crop rotations	Netherlands	crop rotation, soil health, Oldambt system, climate adaptation	https://doi.org/10.5281/zenodo.15647060
SPNA	AgriFuture: Innovative Crop Strategies for Seed Potato Cultivation	Sustainable seed potato systems	Netherlands	potato cultivation, biodiversity, chemical reduction, climate resilience	https://doi.org/10.5281/zenodo.15647041
SPNA	Green Fertilizers: Lucerne and Clover Pellets for Winter Wheat	Plant-based fertilization	Netherlands	lucerne, clover, winter wheat, nutrient management	https://doi.org/10.5281/zenodo.15647033
SPNA	Plant-Based Fertilizer and Natural Crop Protection in Seed Potatoes	Natural pest and nutrient management	Netherlands	aphid control, grass-clover, green manures, seed potatoes	https://doi.org/10.5281/zenodo.15647027
WU	Cut-and-Carry Green Manure: Opportunities for Plant-Based Nutrient Management in Potato Systems	Plant-based nutrient cycling	Netherlands	green manure, clover silage, soil health, circular fertilization	https://doi.org/10.5281/zenodo.15647020
SPNA	Planty Organic: Long-Term Crop Rotation with Plant-Based Nutrition	Plant-based fertilization	Netherlands	organic farming, cover crops, nitrogen efficiency, plant-based inputs	https://doi.org/10.5281/zenodo.15647108
AU	Grass-Based Cropping Systems: Transforming the Danish Agricultural Landscape	Perennial grass systems and biorefinery	Denmark	perennial crops, biorefining, nutrient leaching, biodiversity	https://doi.org/10.5281/zenodo.15647090
CO	Regional Scale Satellite Monitoring	Remote sensing for NBS monitoring	Denmark	satellite data, NDVI, crop monitoring, decision support tool	https://doi.org/10.5281/zenodo.15647085
KFS	From Grass to Value: Refining Green Biomass for Protein and Nutrients	Green biorefining and circular agriculture	Denmark	biorefinery, protein extraction, circular economy, livestock feed	https://doi.org/10.5281/zenodo.15647082

KFS	Circular Systems in Action: Cascade Utilization and Industrial Symbiosis	Industrial symbiosis and resource efficiency	Denmark	cascade use, PtX, circular economy, green biomass	https://doi.org/10.5281/zenodo.15647070
RRes	Nature-Based Solutions for Insect Pest Management	Insect pest management through NBS	UK	pest control, reduced tillage, companion planting, biodiversity	https://doi.org/10.5281/zenodo.15853864
RRes	Soil Carbon Stewardship and Nature-Based Solutions: Managing Soil Organic Carbon	Soil organic carbon and soil health	UK	SOC, SOM, LSRE, reduced tillage, compost	https://doi.org/10.5281/zenodo.15853852
SZE	Monitoring Nature: Remote Sensing as a Key Enabler of Nature-Based Solutions	Remote sensing for NBS	Hungary	drone monitoring, GIS, NBS evaluation, soil restoration	https://doi.org/10.5281/zenodo.15647014
SZE	Look Into the Soil to Understand the Benefits of NBS for Soil	Soil profile demonstration	Hungary	soil profile, farmer engagement, root development, microbial activity	https://doi.org/10.5281/zenodo.15646995
SZE	Fostering Population Growth of Kestrel (Falco Tinnunculus) in Agricultural Areas	Biological pest control	Hungary	kestrel, vole control, biodiversity, nesting boxes	https://doi.org/10.5281/zenodo.15646985
P4all	Cultivating Innovation – trans4num Hackathon Highlights	Hackathon-based innovation in NBS	Europe/China	innovation, digital tools, hackathon, nutrient management	https://doi.org/10.5281/zenodo.15647062
UHOH	Small Actions in Light of Transformation	Stepwise NBS implementation	Multiple (trial sites)	circular nutrients, incremental change, local adaptation, stakeholder engagement	https://doi.org/10.5281/zenodo.15646956

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 abstracts collectively support key project aims, including improving soil health and nutrient cycling, reducing dependence on synthetic inputs, fostering biodiversity, and supporting circular nutrient management. They also reflect real-world complexities, including trade-offs, barriers to adoption, and the need for context-specific strategies.

Importantly, the practice abstracts translate scientific knowledge into practical, accessible formats for farmers and advisors, helping bridge the gap between research and practice. Together, they offer valuable insights into the potential of NBS for transforming intensive farming systems and contribute meaningfully to the project's broader goals of system innovation, stakeholder engagement, and knowledge exchange.

4. Dissemination

The trans4num factsheets will be disseminated as downloadable PDF files through a range of strategic platforms to ensure wide accessibility and long-term visibility. Following their submission to in the EIP-Agri database, the factsheets will be made available in the Library section of the trans4num project website, under a dedicated sub-section for practice abstracts.

To enhance discoverability and citation, the PDFs have already been uploaded to Zenodo, where each factsheet has been assigned a Digital Object Identifier (DOI). These DOIs will also be cross-referenced in the EIP-Agri database.

In addition, the full set of practice abstracts will be made accessible via the trans4num project page on the EU-FarmBook platform, contributing to the shared European knowledge base for farmers, advisors, and practitioners.

We will launch a communication campaign via its LinkedIn page to share the practice abstracts and will also engage the networks of trans4num partners and the projects listed in D5.9 to disseminate practical knowledge more broadly.

5. Next steps

Building on the approach established for the first batch, the preparation of the second round of practice abstracts will follow a similar workflow. Partners will once again be invited to contribute practical insights and tested solutions emerging from their activities. Particular attention will be given to encouraging contributions from Chinese project partners, thereby reinforcing the project's commitment to Europe-China knowledge exchange and mutual learning.

In parallel, efforts will continue to disseminate and promote the first batch of practice abstracts. This includes the translation of the factsheets into the project's working languages to ensure broader accessibility and uptake across diverse regions and user groups.

The writing and review process for the second batch will commence in early 2026, with finalisation and submission planned for Month 44 (July 2026), in line with Deliverable D5.7.

Table 1 First ideas of Practice Abstracts for D5.7

Partner	Title
AU	Decision support tool
AU	Biorefinery – implementation
AU	Biorefinery - function
RRes	NBS for weeds management
RRes	NBS for diseases management

6. Annexes

These annexes show the template that was used by the partners to create the ptrans4num Practice Abstracts, the 17 trans4num Practice Abstracts and the EIP-Agri generated template after submission.

TITLE OF YOUR SOLUTION

Summary

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The need

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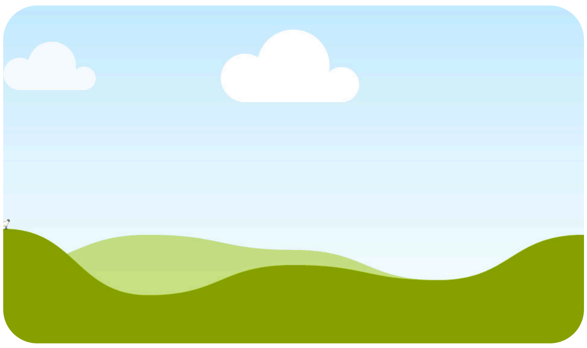

The benefits

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TITLE OF YOUR SOLUTION

trans4num solution

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What were the challenges / limitations in the implementation process?

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

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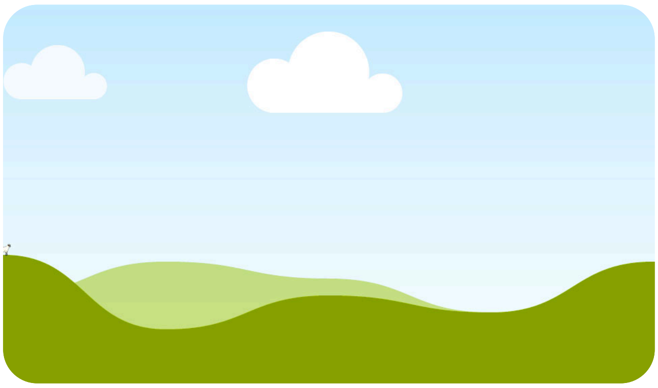
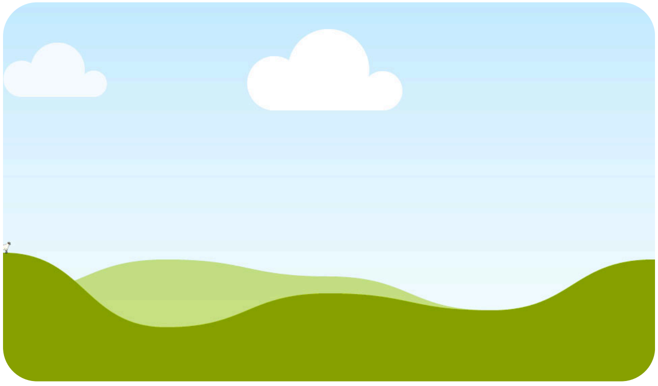
TITLE OF YOUR SOLUTION

More information

- You can use this space to add more info about the solution or and other resources/links relevant for your solution.



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GREEN FERTILIZERS: LUCERNE AND CLOVER PELLETS FOR WINTER WHEAT

Summary

Plant-based fertilizers offer promising opportunities to make grain cultivation more sustainable. Grains have a high nitrogen demand, making this crop particularly suitable for reducing CO_2 emissions. Research into the potential of plant-based fertilizers increases the likelihood of a shift toward more sustainable grain farming.

The need

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 prices have 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 benefits

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 in the coming years.

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GREEN FERTILISERS: LUCERNE AND CLOVER PELLETS FOR WINTER WHEAT

trans4num solution

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.

What were the challenges / limitations in the implementation process?

- How do Lucerne and grass pellets compare to my standard fertilizer?
- Can Lucerne or grass pellets reduce my dependency on conventional fertilizers?
- What specific benefits do Lucerne and grass pellets provide in my fields?
- Do Llucerne or grass pellets have any impact on the next crop, such as cover crops or the following main crop?
- Is the use of plant based fertilizer increasing the risk of weed pressure?
- Does soil life improve when using plant-based fertilizers like grass-clover?

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

- 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.

GREEN FERTILISERS: LUCERNE AND CLOVER PELLETS FOR WINTER WHEAT

More information

- SPNA article on Plant-based fertilization
- Caring farmers - 100% vegetable fertilizer - is it possible?
- trans4num Dutch NBS site

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GRASS-BASED CROPPING SYSTEMS: TRANSFORMING THE DANISH AGRICULTURAL LANDSCAPE

Summary

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.

The need and the benefits

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.

Currently, due to a lack of incentives for farmers, there is unexploited potential to mitigate the negative impacts of agriculture by replacing traditional feed crops with perennial grasses. However, with the recent advancements in green biorefining technologies, economic incentives could be created. A remaining challenge, however, is establishing reliable production and supply chains that ensure stability and security for all stakeholders, including the development of market opportunities, supportive policies, new technologies and education. Developing these systems will be crucial to unlocking the potential of perennial grasses, both as a viable business strategy and an effective environmental solution.

The function

The substitution of grass on cereal and maize fields can 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.

Hence, replacing cereal and maize with grasslands with minimum management, strengthened collaboration of farmers/landowners and circularity at the landscape scale with maximum reuse of co-products may help to reduce the overall loss of GHG and nutrients, improve biodiversity and create more sustainable landscapes in a landscape dominated by agriculture.

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GRASS-BASED CROPPING SYSTEMS: TRANSFORMING THE DANISH AGRICULTURAL LANDSCAPE

trans4num solution

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.

This highlights the importance of involvement of the actors of the landscape. In our research, we conduct interviews with key stakeholders, including early adopters in the green biorefining industry and farmers representing diverse production systems. These interviews provide insights into the opportunities and barriers faced by different stakeholders in the evolving industry. Additionally, we organise stakeholder workshops to disseminate and share knowledge between stakeholders and facilitate collective discussions on the possibilities and challenges in establishing biomass supply chains and collaborative networks between farmers.

What were the challenges / limitations in the implementation process?

- 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

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

- A strong production chain

GRASS-BASED CROPPING SYSTEMS: TRANSFORMING THE DANISH AGRICULTURAL LANDSCAPE

More information

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

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REGIONAL SCALE SATELLITE MONITORING

Summary

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.

The need

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 a spatial 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.

"We are particularly focused on monitoring crop growth across multiple seasons at the NBS sites, with an emphasis on how effectively crops use available nutrients, especially nitrogen. On a regional scale this can be effectively monitored from multispectral satellite imagery using vegetation indexes like NDVI and NDRE.

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.

Funded by the European Union

The benefits

Satellite monitoring is a cost effective tool for the monitoring of agriculture in large areas. Further, since the data has already been collected, it gives access to medium resolution agricultural data covering large regions throughout the past decade.

Manual data collection, like soil sampling, at individual fields is at best sparse, and with varying degree of details across farms. Data collected with drones, enables very precise high resolution data, however the cost of collecting data, makes it very hard to obtain for large regions, especially in a temporal context, where data has to be fetched throughout the growth seasons.

Remote sensing makes the trade-off where precision 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.

The remote sensing satellite data enables timeseries 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.

REGIONAL SCALE SATELLITE MONITORING

trans4num solution

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.

We utilize Deep Learning models to classify the individual crops, over previous and current growth seasons, since this context is a requirement for the model to work. For the primary crops this can be done with very high precision using multispectral satellite imagery.

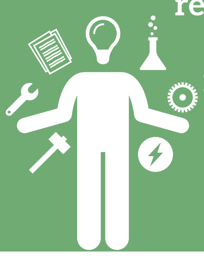
We further monitor the variation in growth across the entire region using indexes like NDVI and NDRE, in order to rectify the errors in the tabular values, which is otherwise the best available input for the Decision Support Tool.

Further we believe that we can monitor the crops ability to utilise the available nitrogen, through the growth of crops and especially cover crops in the area, giving a much more refined understanding of the leaching effect of the individual crops throughout the region.

What were the challenges / limitations in the implementation process?

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.



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

An effective compute environment capable of storring and processing large amounts of data.

REGIONAL SCALE SATELLITE MONITORING

More information

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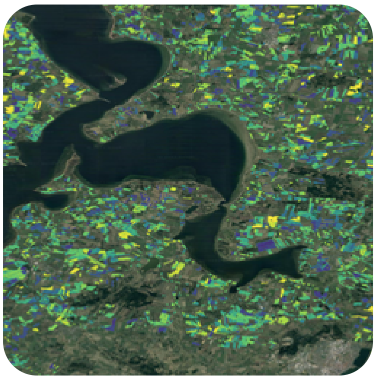

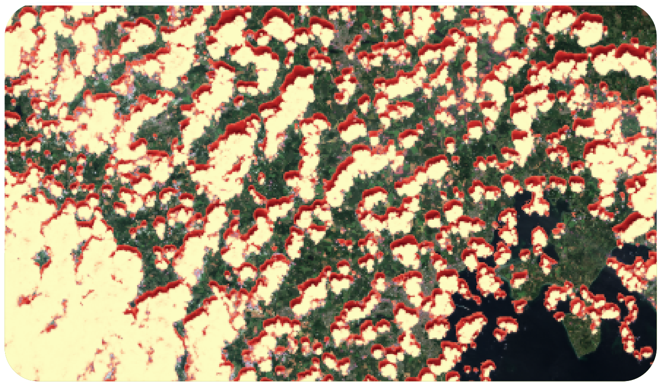

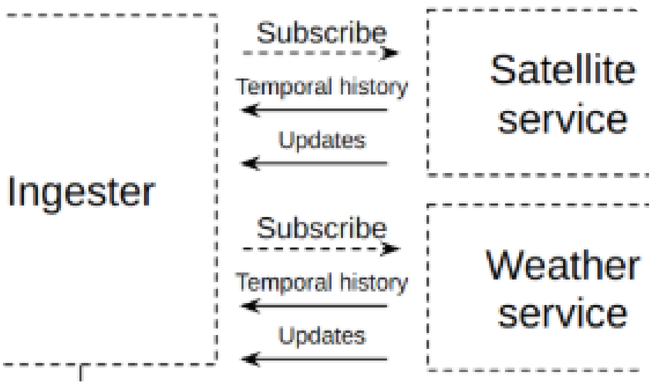

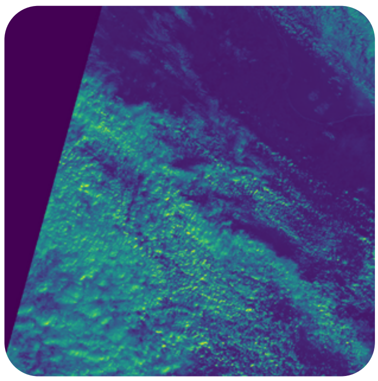

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Learn more about the project at https://trans4num.eu/en/

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FROM GRASS TO VALUE: REFINING GREEN BIOMASS FOR PROTEIN AND NUTRIENTS

Summary

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.

The need

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.

The 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.

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FROM GRASS TO VALUE: REFINING GREEN BIOMASS FOR PROTEIN AND NUTRIENTS

trans4num solution

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

Optimizing Through Collaboration

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.

What were the challenges / limitations in the implementation process?

- Managing perishability of pulp (must be processed quickly)
- Scaling the refining process
- Coordinating supply between fields and refineries

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

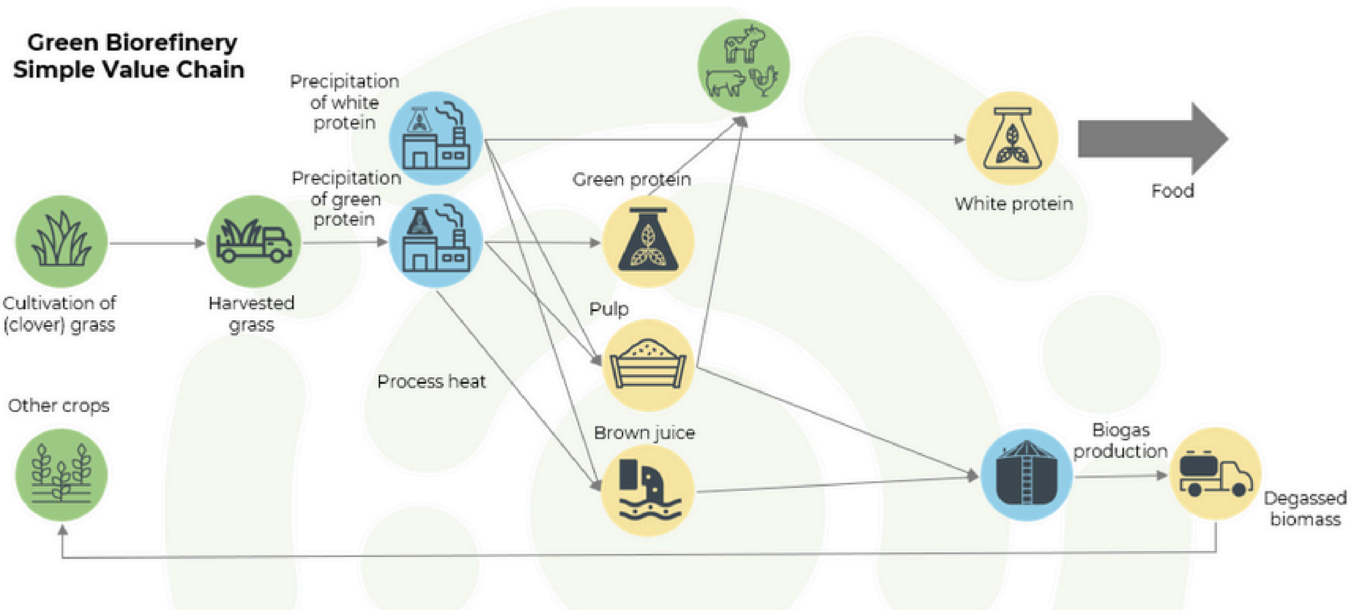
- Biorefining infrastructure (factories, dryers, storage)
- Farmer-refinery logistics coordination
- Knowledge transfer & technical support

FROM GRASS TO VALUE: REFINING GREEN BIOMASS FOR PROTEIN AND NUTRIENTS

More information

Developing commercial products from pulp and brown juice still requires considerable innovation, but the potential is promising - especially since very large quantities of both can be produced.

trans4num Danish NBS site



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CIRCULAR SYSTEMS IN ACTION: CASCADE UTILIZATION AND INDUSTRIAL SYMBIOSIS

Summary

Cascade utilization and industrial symbiosis are central to unlocking the full potential of green biomass. In trans4num, we explore how every part of the plant—from protein to pulp and brown juice—can serve new value chains across food, feed, packaging, and energy.

The need

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 decarbonisation 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

Without coordinated action, we risk losing both valuable resources and opportunities to lead in green innovation.

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The 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

trans4num solution

Cascade Utilization of Green Biomass

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.

Industrial Symbiosis with Power-to-X

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—supporting climate-smart energy cycles

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.

What were the challenges / limitations in the implementation process?

- 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

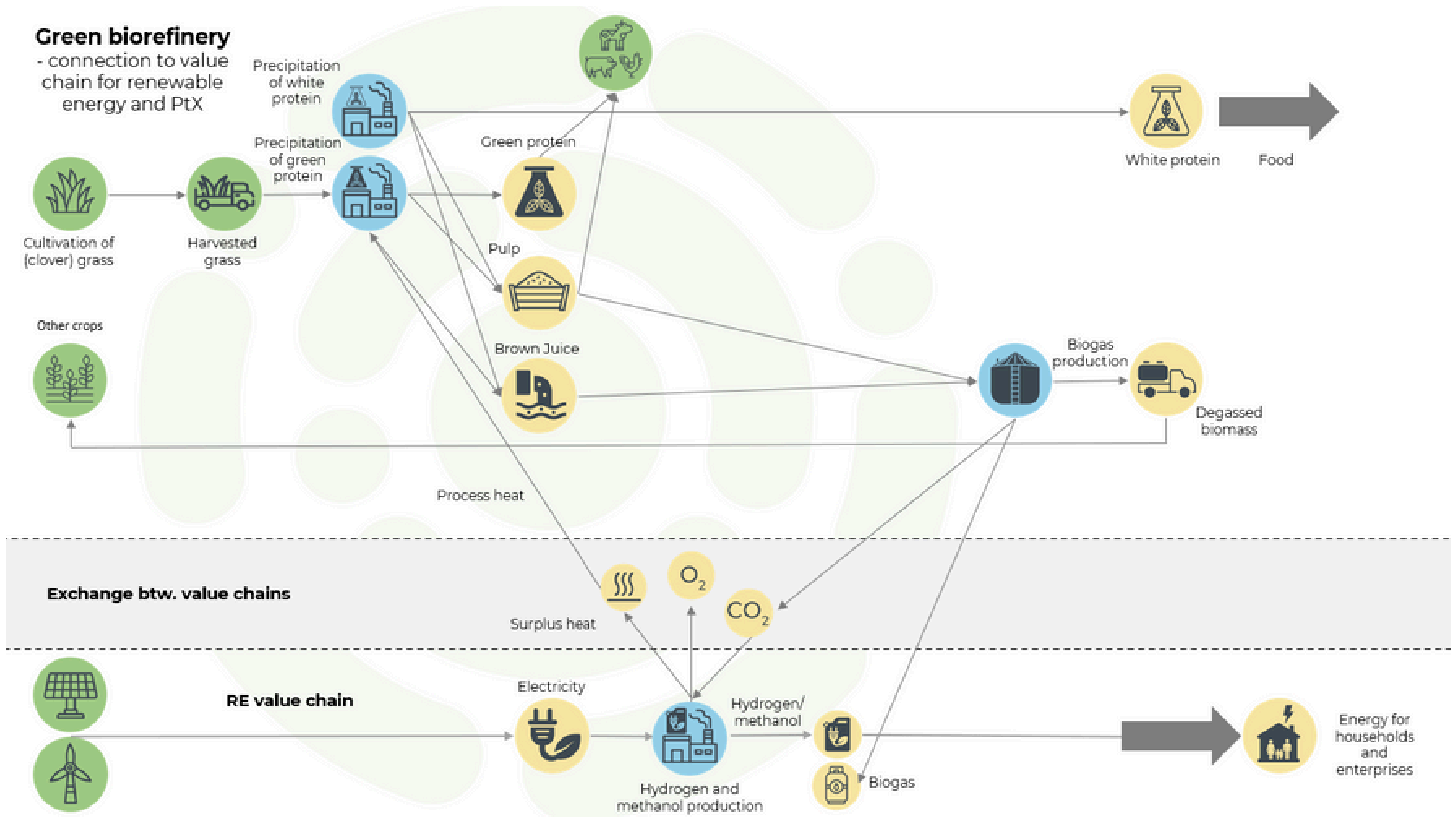
What kind of resources do you need to implement the proposed solution?

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

CIRCULAR SYSTEMS IN ACTION: CASCADE UTILIZATION AND INDUSTRIAL SYMBIOSIS

More information

- trans4num Danish NBS site



CULTIVATING INNOVATION – TRANS4NUM INSPIRE HACKATHON HIGHLIGHTS

Summary

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 need

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.

Hackathons provide a fast-paced, collaborative environment where multidisciplinary teams co-create and test innovative solutions. Hackathons accelerate problem-solving, foster knowledge exchange, and produce actionable results, unlike traditional research projects. Engaging farmers, researchers, and technology experts ensures that solutions are both scientifically sound and field-ready.

The trans4num Hackathon focused on leveraging AI, geospatial data, and digital tools to improve nutrient management, biodiversity, and ecosystem resilience. It also aimed to strengthen international collaboration, particularly between Europe and China, where different agricultural systems face similar sustainability challenges.

By bridging the gap between research and practice, hackathons accelerate innovation, empower young professionals, and drive the real-world adoption of NBS for a more sustainable agricultural future.

The benefits

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.

Key outcomes included AI-driven geospatial 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.

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CULTIVATING INNOVATION – TRANS4NUM INSPIRE HACKATHON HIGHLIGHTS

trans4num solution

The trans4num INSPIRE Hackathon 2024 was a collaborative event designed to accelerate innovation in sustainable nutrient management by integrating NBS, digital technologies, and data-driven approaches. It followed the INSPIRE Hackathon format, encouraging open collaboration and using AI, geospatial analysis, and decision-support tools to develop practical, scalable solutions.

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. While participation from Chinese partners was limited, the hackathon laid the groundwork for stronger international collaboration in future editions.

By fostering interdisciplinary teamwork and digital innovation, the trans4num hackathon generated high-impact solutions that engaged the next generation of agricultural innovators. It advanced the adoption of NBS in real-world farming systems.

What were the challenges / limitations in the implementation process?

The trans4num Hackathon highlighted key challenges that offer valuable lessons for future editions. Participant engagement varied, with some challenges failing to attract interest, highlighting the need for better alignment with expertise and interests. Consortium engagement, particularly from Chinese partners, was lower than expected, requiring stronger incentives and clearer communication. Some participants lacked the necessary expertise, suggesting a need for pre-hackathon training and better selection. Future hackathons should ensure tighter challenge selection, stronger participation strategies, and improved incentives for greater impact.

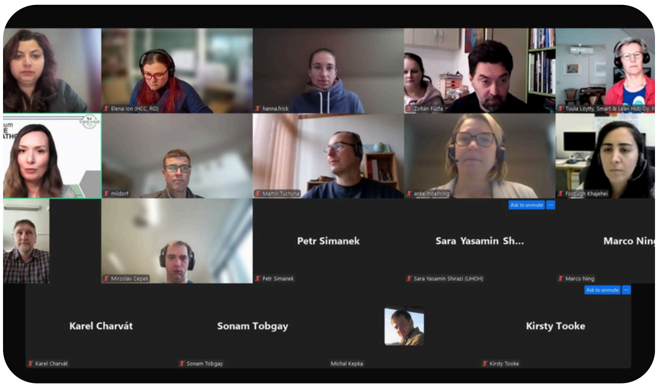
What kind of resources do you need to implement the proposed solution?

Successful implementation requires access to high-quality datasets, particularly in geospatial, meteorological, and soil health data, through partnerships with research institutions and industry stakeholders. Expanding technical training and mentorship will help participants develop the necessary expertise for complex challenges. Strengthening international collaboration, especially with Chinese partners, can improve engagement through hybrid formats and regional hubs. A targeted outreach strategy focused on universities, research institutions, and industry players will attract a diverse participant base and ensure the long-term impact and scalability of hackathon solutions.

CULTIVATING INNOVATION – TRANS4NUM INSPIRE HACKATHON HIGHLIGHTS

More information

- 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
- Watch the videos for the winning challenges
    - Gold award - Fundamentally different case studies of nature-based solutions - how can they be integrated into a common agent-based modelling approach?
    - Silver award - AI-Enhanced Geospatial Analysis for Rural Development Challenge
    - Bronze award - Development of spectacular experimental and demonstration tools and content to establish and spread the use of NBS
- The INSPIRE Hackathon history and past editions from the organisers Plan4All
    - INSPIRE Hackathon



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NATURE-BASED SOLUTIONS FOR INSECT PEST MANAGEMENT

Summary

Modern farming is at a crossroads regarding how to manage the risk of uncontrolled or unmanaged pests within arable agricultural systems. Due to simplified cropping rotations and an over reliance on synthetic chemical control, pests have evolved resistance to pesticides. Furthermore, the use of synthetic chemical control has undesirable impacts for biodiversity, contamination of ecosystems and unwanted negative health impacts, leading to the banning of some pesticides. These pressures have increased the urgency to find alternative solutions

The need

Traditional practices that involve synthetic insecticides have a double-edge sword impact on agricultural practices and concerns for wider food systems. Not only are synthetic insecticides potentially harmful to human health through direct exposure and consumption of contaminated food, but pests are also evolving resistance to them, making usage less effective. For oilseed rape crops, for example, the cabbage stem flea beetle (CSFB) has become a significant threat for a crop that is highly important to UK and northern European farmers. The withdrawal of neonicotinoid seed treatments has meant that pyrethroids are the only available option and resistance is an increasing problem.

The need to reduce the use of synthetic insecticides needs to be balanced with the regulation of pest populations while also in ensuring the health of crops and the environment, something acknowledged by global planning under one health principles. Furthermore, policy decisions made by the EU and the Directive 2009/128/EC on sustainable pesticide use has meant that farmers are being encouraged towards more integrated management plans for controlling pests.

The benefits

Implementing regenerative practices can be a pathway to protecting crops against pests but it is important to anticipate potential trade-offs. Creating a beneficial farm eco-system that works with nature through reduced tillage, habitat creation, crop diversification and organic amendments can potentially improve the ability of crops to tolerate insect pests and encourage natural enemies but leaving crop residues on the surface can increase pressure from slugs.

<u>Stronger healthier plants that resist pests.</u>
Regenerative agriculture improves soil structure and nutrition through compost, cover crops and reduced tillage. Healthy soils with rich biological communities support crop growth and strong plants are less attractive to pests.

<u>Crop rotations break pest cycles.</u>
Many pests are crop specific. By rotating crops the pest's lifecycle is interrupted and reduces the population naturally.

<u>Beneficial insects do the work for you.</u>
Parasitoids are an important group of organisms that control crop pests; they overwinter in the soil and so are protected in reduced tillage systems.

<u>Less reliance on costly chemicals.</u>
Pesticides are expesnive and often unnecessary. Insect Pest Management helps reduce its application, cost, and protects beneficials insects.

<u>A more resilient farming system.</u>
Combining pest control with regenerative agriculture creates a farm ecosystems that works for the farm and the crops. There are fewer pest outbreaks and improves crop health overtime.

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NATURE-BASED SOLUTIONS FOR INSECT PEST MANAGEMENT

trans4num solution

The Rothamsted Research Large-Scale Rotation Experiment (LSRE) is testing multiple Nature Based Solution interventions (crop rotations, diversified cropping, min/zero till, organic amendments) deployed in different combinations to assess the impact on crop protection and resilience of crops of different types, with the natural regulation of pests being a key element.

The interventions on the LSRE are being monitored to study the synergies and trade-offs of each approach and to also assess the effects on crop yield and crop condition, and establishment.
Pest control dynamics need to be assessed over the long-term. However, since the LSRE started we have observed large increases in the numbers of parasitoids of oilseed rape pests in the reduced tillage systems. Additionally, other Rothamsted experiments have shown that intercropping (cultivation of more than one crop in the same place) has additionally reduced pollen beetle pests in the crops.

Furthermore, companion plants have also shown benefits in reducing and managing pests by providing the pests with a more preferable plant to divert them away from the crop (e.g., oilseed rape crop with turnip rape as a companion trap crop).

The LSRE is currently being monitored to confirm these responses in contrasting cropping systems.
There is some evidence that where you plant and managing the off-crop habitats is equally important. Flower rich margins can be of a huge benefit to biocontrol and biodiversity or planting a strip of a companion plant in the middle of a crop, for example turnip rape. This has shown to reduce the pest larvae on the crop, highlighting the benefit of plant diversification.

What were the challenges / limitations in the implementation process?

- 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).

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

- 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.

NATURE-BASED SOLUTIONS FOR INSECT PEST MANAGEMENT

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SOIL CARBON STEWARDSHIP AND NATURE-BASED SOLUTIONS: MANAGING SOIL ORGANIC CARBON

Summary

The impact of nature-based solutions (NBS) on soil organic matter (SOM) and soil organic carbon (SOC) is a hot topic. Healthier soils make farms more resilient and efficient. However, there is a knowledge gap on how farmers can benefit from better management of their SOM and SOC.

The need

Carbon represents 50% of SOM, the rest comes from nutrients (N,P,S,+O,H). As microbes, these nutrients provide crops with energy. The microbial activity improves soil structure, water filtration and retention, aeration, and root growth. SOM is an important reservoir of nutrients through microbial activity.

Most carbon is found in soil, meaning SOC is important for regulating the climate. However, SOC is easily lost through conventional farming. Destructure of soil functionality and structure inhibits carbon replacement. Land needs to be managed for soils to be substantial carbon sinks.

However, knowledge gaps mean it isn't clear which sustainable practices or combinations are best to maximize SOC or SOM.

Possible management practices on farmland include a) reducing soil disturbance by switching to low-till or no-till practices or planting perennial crops; b) changing planting schedules or rotations, such as planting cover crops; c) managed grazing of livestock or applying manures; d) applying compost or retaining crop residues to fields.

The effect of any one NBS will depend on whether it is combined with other options. Rothamsted Research's Large-Scale Rotation Experiment (LSRE) is testing all possible combinations of compost, reduced tillage, cover crops and perennial crops in different 'system.'

The benefits

Even small increases in SOM and SOC have been found to be beneficial to soil health and function. Improving SOM and SOC can create efficient use of water and nutrient management and wider eco-systems, including increasing worm populations.

Broad global context also needs to be considered. The global north has organic rich carbon soils which require a responsible approach to managing these carbon stocks. it has been estimated that soils - mostly agricultural ones - could sequester over a billion additional tons of carbon each year.

NBS interventions, such as the ones being used on the LSRE, help to manage SOC and SOM through retaining crop residues, adding organic matter through manures, compost, reducing tillage and soil disruption/compaction and including leys in arable rotations.

Thus, implementing NBS systems may allow SOC to be managed more effectively for long-term health of the soil and has wider beneficial implications for planetary health. NBS systems may therefore provide environments for microbial activity that maintains a flow of nutrient and minerals through the soil and improves soil struture and healthy functions.

SOM can be measured by Loss on Ignition testing, essentially the organic matter is burnt off. However if SOC is being measured through dry combustion the amount of carbon measured can be converted into an estimate of SOM (and vice versa), SOC is reliably measured by carrying out a Dumas test (dry combustion). This analyses the carbon from gasses released by heating up the soil samples in oxygen rich air until it starts to burn, and the amount of carbon dioxide produced is measured.

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SOIL CARBON STEWARDSHIP AND NATURE-BASED SOLUTIONS: MANAGING SOIL ORGANIC CARBON

trans4num solution

The Rothamsted Research Large-Scale Rotation Experiment (LSRE) is testing multiple NBS interventions (crop rotations, diversified cropping, min/zero till, organic amendments) deployed in different combinations to asses the impact on different properties of soil, with SOC and SOM being a key element.

The interventions on the LSRE are being monitored to study the synergies and trade-offs of each approach and to also assess the effects on crop yield and efficiency of fertilizer use.

Soil organic carbon dynamics need to be assessed over the long-term. Because of seasonal effects of weather, short term reductions in SOC were observed in all treatments but, over the longer term, we are seeing consistent benefits of NbS interventions; emphasizing the need for a long term experiment.

SOC increases in the phase of a rotation where the NBS (for example, carbon) is applied but may decrease in the other phase of the rotation. The benefits of an NBS, therefore, were assessed by quantifying the soil carbon across the whole rotation at the level of the 'system'.

After six years, the top five cropping systems in terms of increases in SOC, all had a combination of compost and reduced tillage indicating an additive benefit of these two NBS. These results were from a site with sandy soil meaning the potential for additional carbon storage is limited. We expect to see larger effects from the LSRE site on a heavy clay soil which has a greater capacity for carbon storage.

The management of SOC resources can only be achieved through the monitoring of levels and implementation of strategies to maintain already developed stocks and management of interventions to improve them in the case of degraded soils/

Management interventions include reduced tillage, cover crops, rotational and diversified cropping, direct drilling, application and inclusion of livestock, manures and compost, as well as retaining crop residues and reducing fallow land. All these NBS interventions are linked with enhancements in soil structure, soil organic matter and soil carbon. Improved soil structures provide ecosystem services which include water retention, reducing soil loss, decreasing the need for inputs such as minerak fertilizers and therefore run-off of such inputs into watercourses.

What were the challenges / limitations in the implementation process?

- 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 on glysophate.
- Extreme weather and establishing cover crops in time for growing season.

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

- 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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SOIL CARBON STEWARDSHIP AND NATURE-BASED SOLUTIONS: MANAGING SOIL ORGANIC CARBON

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AGRIFUTURE: INNOVATING CROP ROTATIONS & SOIL HEALTH ON CLAY SOILS

Summary

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 need

The Oldambt region features a distinctive arable farming structure, largely shaped by its heavy clay soils. While these soils are highly fertile, they limit crop diversity. As a result, the area is dominated by cereal crops, particularly grains, and relatively few root crops like potatoes or carrots are grown.

The landscape is defined by wide expanses of grain fields (especially winter cereals) interspersed with sugar beet, rapeseed, and an increasing share of seed onions. This crop rotation system is known as the Oldambt crop plan, a unique approach within the Netherlands. In other regions, root crops often play a more prominent role.

Although cereals are generally considered break crops, the tight grain-to-grain rotation typical of the Oldambt demands closer attention. Disease pressure, soil health, and maintaining crop yields remain key challenges for the long-term sustainability of arable farming in the region.

The benefits

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.

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AGRIFUTURE: INNOVATING CROP ROTATIONS & SOIL HEALTH ON CLAY SOILS

trans4num solution

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 (Candidates for 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

What were the challenges / limitations in the implementation process?

- 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

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

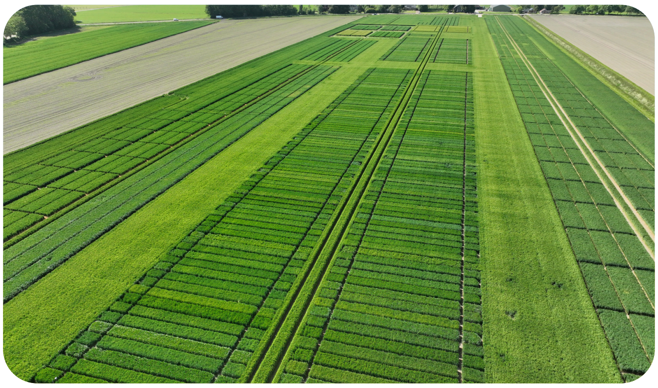
- Access to appropriate crop rotations, limiting cereals to a maximum of 50% and incorporating spring crops
- Machinery and/or robotics for effective weed control as an alternative to chemical herbicides
- Agronomic support and knowledge sharing to reduce reliance on chemical inputs, including the use 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: INNOVATING CROP ROTATIONS & SOIL HEALTH ON CLAY SOILS

More information

- SPNA webpage on AgriFuture
- trans4num Dutch NBS site



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AGRIFUTURE: INNOVATIVE CROP STRATEGIES FOR SEED POTATO CULTIVATION

Summary

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 need

Dutch arable farming — like livestock farming — is facing a major and complex challenge. 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?

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The 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.

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: INNOVATIVE CROP STRATEGIES FOR SEED POTATO CULTIVATION

trans4num solution

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

What were the challenges / limitations in the implementation process?

- 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.

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

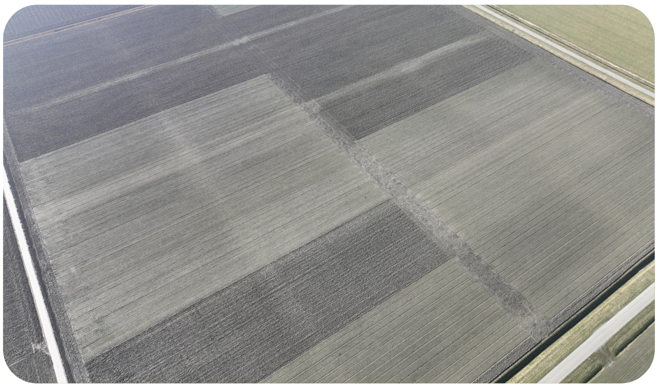
- Knowledge of the latest techniques and innovations
- Crop expertise within a renewed, future-oriented crop rotation system
- Active collaboration with various partners to expand knowledge and share experiences

AGRIFUTURE: INNOVATIVE CROP STRATEGIES FOR SEED POTATO CULTIVATION

More information

- SPNA website for AgriFuture
- Dutch paper on Integral control of PVY 9 in seed potatoes
- Dutch article on applying straw to reduce aphid pressure on seed potatoes
- Video: Cover crops in a potato based crop rotation
- trans4num Dutch NBS site



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PLANT-BASED FERTILIZER AND NATURAL CROP PROTECTION IN SEED POTATOES

Summary

This research focuses on the use of green manures (such as grass-clover and/or grass) in rotation with seed potatoes. It examines the nitrogen effect of these green manures as well as their impact on aphid abundance in potato crops. A key part of the study involves monitoring aphid populations, as there is evidence suggesting that certain green manures and other soil improvement practices may reduce aphid numbers, potentially leading to more efficient use of soil nutrients.

The need

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.

The benefits

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. Because the green manure begins growing earlier than the potato plant, aphids may settle on the green manure instead—potentially reducing the risk of virus transmission to the crop.

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PLANT-BASED FERTILIZER AND NATURAL CROP PROTECTION IN SEED POTATOES

trans4num solutions

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.

What were the challenges / limitations in the implementation process?

- Significant reduction in pesticide use — nearly eliminating aphid control agents and oils used to prevent virus transmission.
- Reduced use of fertilizers.
- Recovery of lost productivity and improved farm resilience and efficiency.
- Increased biodiversity: less chemical use leads to lower impact on ecosystems during cultivation.
- Improved water quality at the regional level, due to reduced leaching of chemicals and fertilizers.

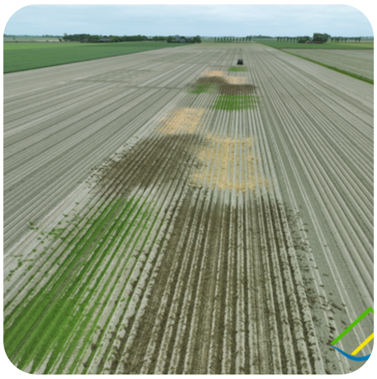
What kind of resources do you need to implement the proposed solution?

- 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.

PLANT-BASED FERTILIZER AND NATURAL CROP PROTECTION IN SEED POTATOES

More information

- Dutch paper on Integral control of PVY 9 in seed potatoes
- Dutch article on applying straw to reduce aphid pressure on seed potatoes
- Video: Cover crops in a potato based crop rotation
- trans4num Dutch NBS site



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PLANTY ORGANIC: LONG-TERM CROP ROTATION WITH PLANT-BASED NUTRITION

Summary

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 materials to feed the soil. The main crops include potatoes, pumpkins, grains, and grass-clover.

The need

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.

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—a key benefit, especially for organic farmers.

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. It also supports a more circular, plant-based farming system.

Vegan-Friendly Certification

With growing demand for plant-based products, avoiding animal inputs can help meet vegan certification standards—opening doors to niche markets and premium pricing.

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.

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PLANTY ORGANIC: LONG-TERM CROP ROTATION WITH PLANT-BASED NUTRITION

trans4num solution

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**

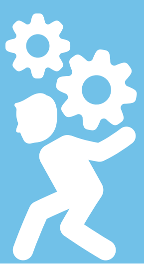
Since 2022, more than 20 arable farmers have started applying our knowledge to improve their use of cover crops—supported by one of the Netherlands' largest farmer cooperatives. Their advisors play a key role in sharing practical results.

- **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. Nature-Based Solutions (NBS) guide our approach—combining innovation with environmental care.



What were the challenges / limitations in the implementation process?

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.

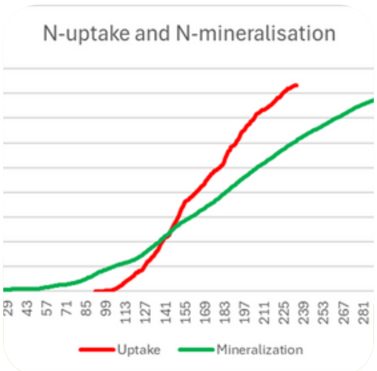
What kind of resources do you need to implement the proposed solution?

Modeling tools like N-DICEA: Tools such as N-DICEA can help us analyze and even predict the optimal fertilization strategy by simulating nitrogen dynamics in organic systems. These models are essential for aligning nutrient supply with crop demand more precisely.
More knowledge about soil microbiology: We also urgently need a better understanding of the microbiological processes in the soil. Soil life plays a key role in how nutrients become available to plants—especially in systems that rely entirely on organic and plant-based inputs.

PLANTY ORGANIC: LONG-TERM CROP ROTATION WITH PLANT-BASED NUTRITION

More information

- trans4num Dutch NBS site



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MONITORING NATURE: REMOTE SENSING AS A KEY ENABLER OF NATURE-BASED SOLUTIONS

Summary

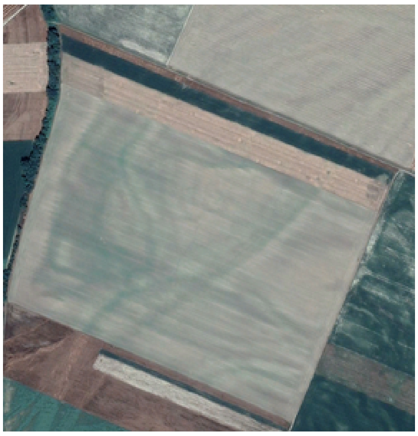
Remote sensing technologies offer a powerful toolkit for supporting the implementation, monitoring, and evaluation of Nature-Based Solutions (NBS). By providing spatially explicit, up-to-date data on land cover, vegetation health, hydrology, and more, remote sensing enables practitioners to design better interventions and measure their impact over time.

The need

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.

Furthermore, remote sensing facilitates cross-scale analysis and comparison between sites, enabling stakeholders to learn from different contexts and refine their approaches. Its integration with participatory methods and local knowledge can enhance inclusiveness and legitimacy in NBS design and evaluation.



The benefits

Remote sensing supports NBS implementation in a variety of strategic ways:

Scalability: Satellite data enables consistent monitoring across cities, regions, or even entire countries. This allows planners to prioritize interventions based on large-scale ecosystem trends.

Repeatability: Frequent data acquisition supports monitoring of seasonal dynamics, vegetation growth cycles, and the timing of ecological responses to NBS.

Cost-efficiency: Open-access programs such as Copernicus (Sentinel) and Landsat reduce monitoring costs, making remote sensing accessible to a wide range of stakeholders.

Integration potential: When combined with field surveys, IoT sensors, or modeling approaches, remote sensing enhances multi-source environmental assessment.

Transparency and accountability: Publicly available remote sensing data strengthens reporting mechanisms and builds trust through visual, data-driven storytelling.

Indicator support: Enables the tracking of multiple relevant indicators such as vegetation indices (NDVI), land surface temperature, water availability, or urban heat island effects.

Climate resilience: Time-series analyses help assess long-term changes and trends, providing key information for adaptive NBS strategies in the face of climate uncertainty.

Early warning and risk assessment: Remote sensing helps detect early signs of environmental stress, such as drought, flooding, or land degradation, enabling proactive management and timely adaptation of NBS interventions.

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MONITORING NATURE: REMOTE SENSING AS A KEY ENABLER OF NATURE-BASED SOLUTIONS

trans4num solution

Within the trans4num project, a dedicated Nature-Based Solutions (NBS) site in Hungary was developed to demonstrate how remote sensing and geospatial data can support sustainable land management and ecological restoration. The site serves as a real-world example of how data-driven approaches can guide and monitor NBS interventions.

The implementation relies on an integrated use of drone-based monitoring, and GIS analysis to capture changes in land cover, vegetation health, and water dynamics. These tools provide timely, spatially detailed information that supports adaptive management and long-term impact assessment.

Drones play a key role in the monitoring strategy, offering high-resolution imagery and flexibility in capturing localized environmental changes. They complement satellite data by filling spatial and temporal gaps, particularly in areas where cloud cover or terrain complexity limits satellite visibility.

The NBS site also emphasizes accessibility and replicability. Using open-source platforms such as QGIS and Google Earth Engine, and leveraging affordable drone technology, the trans4num approach ensures broader adoption, especially by smaller municipalities or civil organizations with limited resources.

Capacity-building is a central element of the initiative. Trainings, workshops, and knowledge exchange activities are organized to equip local stakeholders with the skills needed to operate drones, process spatial data, and interpret results in a meaningful way.

In sum, the NBS site developed within the trans4num project is a living example of how remote sensing, drones, and institutional collaboration can be combined to support scalable, effective, and inclusive Nature-Based Solutions.

What were the challenges / limitations in the implementation process?

- 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.

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

- 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.

MONITORING NATURE: REMOTE SENSING AS A KEY ENABLER OF NATURE-BASED SOLUTIONS

More information

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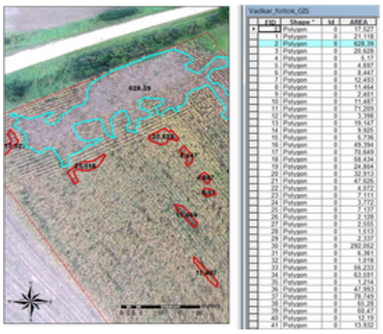

Funded by the European Union

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LOOK INTO THE SOIL TO UNDERSTAND THE BENEFITS OF NBS FOR SOIL

Summary

Soil profile investigation is a powerful demonstration method to visualize the impact of Nature-Based Solutions (NBS) such as no/min-till farming, and manure application and cover crops on soil structure. By examining soil layers, farmers can empirically observe improvements and better understand the benefits of sustainable agricultural practices.

The need

Soil profile demonstrations are essential because soil remains a "black box" for many farmers. While the benefits of NBS solutions exist, they are often hidden beneath the surface. Through soil profile analysis, we can make these advantages visible, offering farmers tangible proof that adopting sustainable practices improves soil health and fertility. By digging into the soil, we can clearly show the effects of different management techniques, making it easier for farmers to see and believe in the changes happening beneath their feet. Farmers often rely on surface indicators to gauge soil health, but these can be misleading. A soil profile investigation allows them to observe firsthand how sustainable practices enhance root development, microbial activity, and soil aggregation. With this approach, we transform abstract scientific concepts into practical, observable benefits. By making the invisible visible, we empower farmers with knowledge that drives informed decision-making and long-term sustainability.

By digging into the soil, we can clearly show the effects of different management techniques, making it easier for farmers to see and believe in the changes happening beneath their feet. Farmers often rely on surface indicators to gauge soil health, but these can be misleading. A soil profile investigation allows them to observe firsthand how sustainable practices enhance root development, microbial activity, and soil aggregation. With this approach, we transform abstract scientific concepts into practical, observable benefits. By making the invisible visible, we empower farmers with knowledge that drives informed decision-making and long-term sustainability.

The benefits

Empirical understanding is key to changing farming practices. A soil profile demonstration provides undeniable visual evidence of soil improvements, such as enhanced soil structure, increased organic matter, and better water retention. Farmers can see firsthand how cover crops, reduced tillage, and organic amendments like manure contribute to healthier soil.

Many of these positive changes are not immediately visible from the surface, making it crucial to look deeper into the soil. By showcasing real results, we help bridge the gap between scientific knowledge and practical farming, ensuring that farmers gain trust in NBS solutions and integrate them into their daily work.

Demonstrations reveal differences in soil porosity, root penetration, and biological activity, reinforcing the connection between management choices and soil quality. Farmers witnessing these changes become more confident in adopting and maintaining NBS practices.

Additionally, soil profile investigations facilitate knowledge-sharing among farmers, fostering a collaborative approach to regenerative agriculture. When farmers can visually assess the long-term benefits of NBS, they are more likely to make informed decisions that benefit both their land and productivity. Ultimately, these insights drive the transition toward more resilient and sustainable farming systems.

Funded by the European Union

LOOK INTO THE SOIL TO UNDERSTAND THE BENEFITS OF NBS FOR SOIL

trans4num solution

As part of a trans4num event, we conducted soil profile investigations to highlight the differences within fields. By digging soil pits, we revealed variations in soil composition—one area showed a gravel layer while another displayed a rich, humus-laden topsoil. These contrasts underscore the need for site-specific soil management. By engaging farmers in this hands-on demonstration, we made the results of NBS solutions tangible, helping participants understand the impact of sustainable farming practices on soil health.

Through this experience, they gained insights into how their soil evolves when they apply NBS, reinforcing their commitment to regenerative agriculture. Farmers observed firsthand how different practices influence soil stability, root growth, and moisture retention. These observations strengthen their confidence in sustainable strategies, encouraging them to implement site-adapted NBS approaches.

Through this experience, they gained insights into how their soil evolves when they apply NBS, reinforcing their commitment to regenerative agriculture. Farmers observed firsthand how different practices influence soil stability, root growth, and moisture retention. These observations strengthen their confidence in sustainable strategies, encouraging them to implement site-adapted NBS approaches.

By connecting soil characteristics with management history, we empower farmers to refine their techniques for optimal results. Trans4num events foster a dynamic exchange of knowledge, where real-world evidence supports the widespread adoption of regenerative farming.

What were the challenges / limitations in the implementation process?

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.

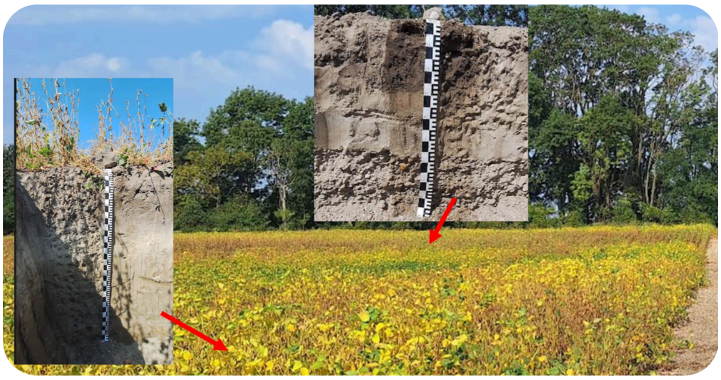
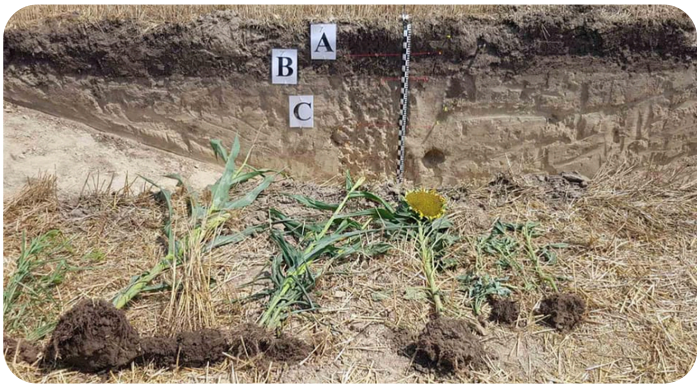
What kind of resources do you need to implement the proposed solution?

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.

LOOK INTO THE SOIL TO UNDERSTAND THE BENEFITS OF NBS FOR SOIL

More information

- trans4num NBS site in Hungary
- Soil section demonstration in Kimle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Learn more about the project at https://trans4num.eu/en/

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FOSTERING POPULATION GROWTH OF KESTREL (FALCO TINNUNCULUS) IN AGRICULTURAL AREAS

Summary

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.

The need

In the last decade, intensive agriculture has become increasingly widespread. Thanks to the agri-digitalisation and precision agriculture this sector is starting to become more industrial. The goal for the farmers is the same: each year get more yields from a given field, using up to dates technologies.

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 determing factor in many farmers yields. Due to the climatic changes, no tillage agriculture and the regulatory enviroment, 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 (for example the hooded crow (corvus cornix)).

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).

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FOSTERING POPULATION GROWTH OF KESTREL (FALCO TINNUNCULUS) IN AGRICULTURAL AREAS

trans4num solution

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.

"In the last ten years we have been able to increase the breeding pairs at least tenfold by placing the nests." The last five years shows, that after the collapse of a common vole gradation, we can see a decrease in the common kestrel individual numbers. That indicates that beside the nesting places, the number of the prey animals is also a big factor in the population trends.

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.

What were the challenges / limitations in the implementation process?

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.

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

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.

FOSTERING POPULATION GROWTH OF KESTREL (FALCO TINNUNCULUS) IN AGRICULTURAL AREAS

More information

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- Birdphotography.hu

Funded by the European Union

SMALL ACTIONS IN LIGHT OF TRANSFORMATION

Summary

Transforming agricultural practices—or entire farming systems—may seem ambitios 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.

The need

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 in significant 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.

The benefits

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.** This collaborative environment facilitates the exchange of experiences, challenges, and solutions, thereby building a strong support system that can accelerate innovation adoption across regions.

By reflecting on the outcomes of each incremental change, farmers can continuously refine their practices. This ongoing evaluation process is crucial—it allows for adjustments based on real-world performance, ensuring that practices not only meet immediate operational needs but also contribute meaningfully to the goal of circular nutrient management. This reflective cycle fosters a culture of continuous improvement and learning, making the transition more resilient to unforeseen challenges.

Furthermore, a stepwise transformation process lowers risks associated with radical changes by breaking down the transformation into manageable phases. Each small success reinforces confidence and builds momentum, which can eventually lead to more substantial systemic shifts.

The benefits extend to the environmental realm as well, as each incremental improvement can result in reduced fertilizer costs, better soil health, enhanced water quality, and increased biodiversity.

Ultimately, this approach supports sustainable agricultural development that benefits current farm operations while ensuring a viable future for the next generations.

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the European Union

SMALL ACTIONS IN LIGHT OF TRANSFORMATION

trans4num solution

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

Incremental steps are designed not just as isolated improvements, but as interconnected milestones that gradually shift the overall system towards circular nutrient management. Each small transition—from initial trials to broader implementation—adds to the momentum of change, demonstrating the practical benefits and feasibility of new approaches. Moreover, by continuously reflecting both short-term barriers (such as resource limitations and knowledge gaps) and lock-ins (like entrenched intensive practices and weak governance structures), the trans4num framework is able to dynamically navigate interventions in a way that ensures their transformative potential through stepwise adaptations. The solution also emphasizes scalability and adaptation. As successful local innovations are identified, they can be scaled out and up to other contexts, ensuring that the cumulative impact of individual initiatives contributes to the overarching goal of a circular, sustainable nutrient management system. This adaptive framework not only supports current improvements but also lays the groundwork for long-term structural changes.

What were the challenges / limitations in the implementation process?

A key challenge in implementing transformative nutrient management lies in identifying and addressing barriers and drivers within complex agricultural systems. It requires an understanding of the current lock-ins—such as entrenched practices, institutional inertia, power dynamics and resource limitations—that can hinder change. Additionally, practitioners must continuously reflect on their own actions, knowledge, and limitations to ensure that each step taken genuinely contributes to transformation. This reflective process is essential to adapt strategies and overcome both immediate obstacles and entranched constraints over time.

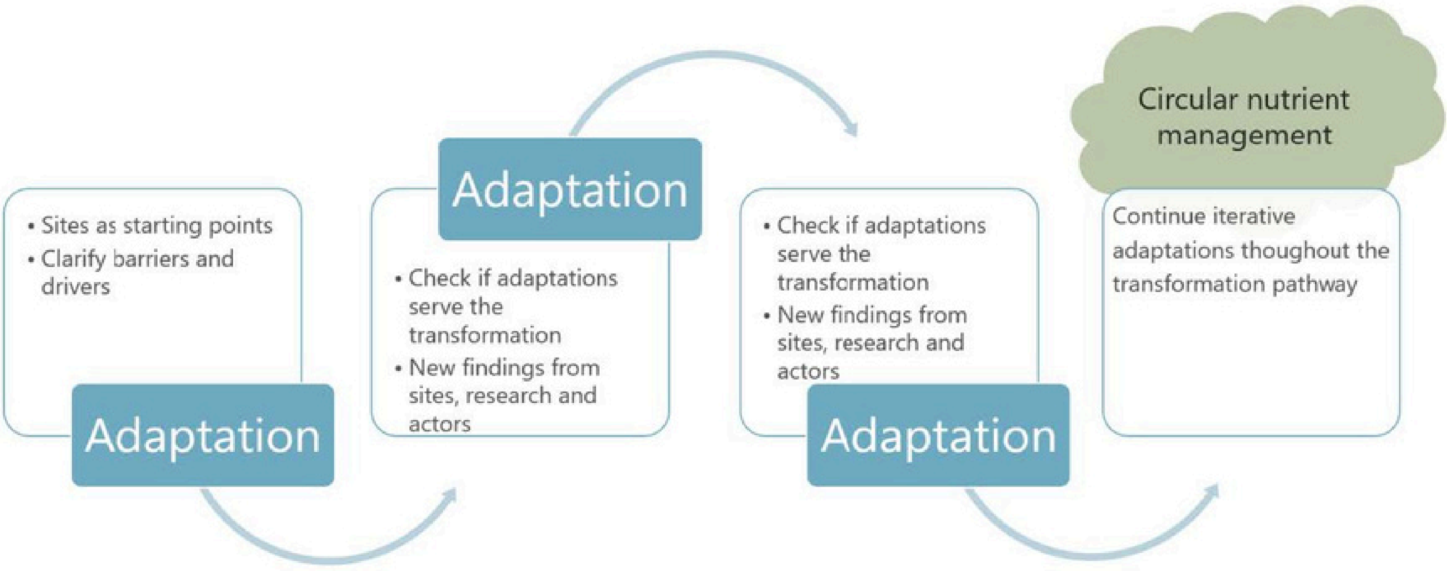
What kind of resources do you need to implement the proposed solution?

Successfully implementing this solution calls for the mobilization of human and institutional resources, particularly by building networks of like-minded individuals and initiatives. Leveraging the experience of those who have already navigated similar practices is valuable, as they can share insights on effective strategies as well as potential hindering factors. Access to collaborative platforms, technical expertise, and financial support further strengthens the capacity to trial, adapt, and scale out NBS across diverse farming contexts.

SMALL ACTIONS IN LIGHT OF TRANSFORMATION

More information

- Report on transformation pathways towards innovative NBS
- trans4num NBS site in Denmark
- trans4num NBS site in Hungary
- trans4num NBS site in The Netherlands
- trans4num NBS site in The United Kingdom
- trans4num NBS site in China



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CUT-AND-CARRY GREEN MANURE: OPPORTUNITIES FOR PLANT-BASED NUTRIENT MANAGEMENT IN POTATO SYSTEMS

Summary

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.

The need

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.

The benefits

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.

While these systems can support soil biology and reduce reliance on external inputs, our results suggest that extra steps—like combining with compost or adjusting the timing of application—are needed to maintain productivity. This approach has potential, but it needs careful management to work well in practice.

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CUT-AND-CARRY GREEN MANURE: OPPORTUNITIES FOR PLANT-BASED NUTRIENT MANAGEMENT IN POTATO SYSTEMS

trans4num solution

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), and
- 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.

What were the challenges / limitations in the implementation process?

- Nutrient release didn't match crop demand, especially during the later growth stages when tubers were developing. This limited nutrient availability when the crop needed it most.
- Timing of application was difficult to optimize, as organic inputs decomposed quickly in early spring, releasing nutrients before the crop could use them — especially during wet periods.
- Different potato varieties were used in conventional and organic systems, which is realistic for practice but complicates direct comparisons of outcomes.

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

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.
Possibly microbial inoculants to boost nutrient mineralisation and availability.

CUT-AND-CARRY GREEN MANURE: OPPORTUNITIES FOR PLANT-BASED NUTRIENT MANAGEMENT IN POTATO SYSTEMS

trans4num

More information

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- Kuzyakov & Xu (2013) "Competition between roots and microorganisms for nitrogen"
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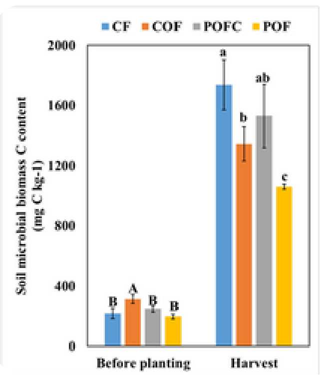
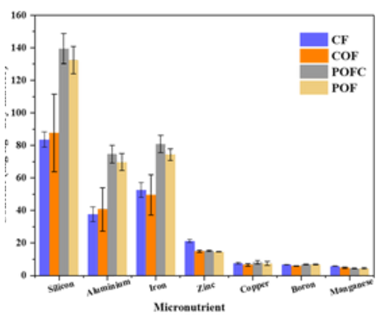
Lead study:
WU & SPNA





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

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EU CAP NETWORK

PROJECT - RESEARCH AND INNOVATION

Transformation for sustainable nutrient supply and management

PROJECT IDENTIFIER: 2022HE_101081847_TRANS4NUM

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- WP5 leader - Communication team

Discover website

Innovation, knowledge exchange & EIP-AGRI

ONGOING | 2022 - 2026

Denmark, Germany, Hungary, Netherlands, Romania, Other, 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

17 Practice Abstracts

1. 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

Geographical Location

Deutschland

Danmark

Nederland

Magyarország

United Kingdom

Additional information

A Gradual Yet Transformative Approach

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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

2. 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

Geographical Location

- Deutschland
- Česko
- Magyarország
- Nederland
- United Kingdom
- Schweiz/Suisse/Svizzera

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

3. 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.

Soil carbon stewardship and Nature-based solutions: Managing Soil organic carbon

Geographical Location

United Kingdom

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.

4. 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

Geographical Location

United Kingdom

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.

5. 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…

Geographical Location

Nederland

Noord-Nederland

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

6. 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

Geographical Location

Nederland

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.

7. 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

Geographical Location

Nederland

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.

8. 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

Geographical Location

Nederland

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.

9. 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

Geographical Location

Nederland

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

10. 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

Geographical Location

Nederland

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

11. 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

Geographical Location

Magyarország

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

12. 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

Geographical Location

Magyarország

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.

13. 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

Geographical Location

Baranya

Magyarország

Győr-Moson-Sopron

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).

14. 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

Geographical Location

Danmark

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.

15. 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

Geographical Location

Danmark

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

16. 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

Geographical Location

Danmark

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.

17. 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

Geographical Location

Danmark

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

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