2nd Report on NBS cases´ implementation and transdisciplinary evaluation in Hungary, Denmark, Netherlands, and UK

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1. Introduction

This deliverable (D2.3) is the second report on the implementation and transdisciplinary evaluation of the Nature-based Solutions (NBS) cases studied within trans4num. It builds on earlier work reported in Deliverable 2.1 (initial site descriptions and implementation plans) and Deliverable 2.2 (first report on NBS cases and early experimentation).

In trans4num, we study innovations in four country sites – Hungary, Denmark, the Netherlands, and the United Kingdom – that contribute to more sustainable nutrient management. These innovations are designed, planned, and implemented at the regional and farm level, on fields and plots. Their significance extends beyond individual farms: they matter for transformation when they are practised by many farmers, across considerable agricultural areas, and when they connect with broader policy frameworks and markets.

The second project year (2024–2025) has been devoted to implementing the selected NBS in practice, observing their performance, and engaging with stakeholders to evaluate both opportunities and challenges. This report collects site-specific narratives from each country, using a storytelling framework to connect technical, social, and policy aspects. The aim is to show not only how experiments are progressing, but also how they link to the broader transformation goals of trans4num: closing nutrient cycles, reducing environmental pressures, and supporting resilient agri-food systems.

2. Methods and protocols

The site storylines presented in this deliverable were developed using a shared methodology, refined across the project's first two years. The approach consisted of two main steps:

Step 1 – Initial site narratives

Each NBS site team prepared a site-specific narrative in the lead-up to the General Assembly (GA) in Denmark in summer 2025. To guide this process, the site leads were asked to reflect on two key questions:

- How does your current work contribute to circular nutrient management?
- What key insights have you gained since the project began—whether from collected data, scientific advancements, or stakeholder feedback?

The responses to these questions formed the first versions of the storylines. These early drafts are included in the appendix as supplementary material.

Step 2 – Refinement through storytelling devices

The initial narratives were then developed into fuller storylines using three heuristic devices introduced by the Rothamsted social science group:

Tensions framework: Each site was asked to identify the policy, social, and economic tensions that shape their work. This highlighted both common challenges across sites (e.g., CAP, inheritance, market viability) and context-specific issues.

Story Arc: Storylines were structured around five stages (exposition, rising action, climax, falling action, resolution). This allowed each site to explain not only what they were doing, but why it matters and where it could lead.

Story Elements: Each site identified the characters (e.g., farmers, industries, scientists, policymakers), settings (e.g., Limfjord catchment, Szigetköz), challenges, and resolutions relevant to their innovation.

This process was supported by a dedicated NBS Storytelling PowerPoint, which introduced the storytelling devices through examples, guiding questions, and exercises. The Results-Interpretation-Outcomes-Operational-Vision (RIOOV) drafts were reviewed against these devices, and feedback was shared with site teams. Importantly, this showed that most elements of the stories already existed in the drafts and only required refining and making some aspects more explicit.

At the GA in Denmark, draft storylines were presented in 10-minute group sessions. Sites ranked their tensions, identified the main characters, and discussed key points for each stage of the story arc. This interactive process helped sharpen both the narrative and the cross-site comparability.

Protocols and Review

In addition, the storylines were aligned with protocols developed in project Tasks 1.2 and 1.4. These included approaches for stakeholder integration, environmental and agronomic monitoring, and linking site-level activities to wider transformation pathways. Drafts were reviewed by the Rothamsted team for clarity, tension analysis, and alignment with trans4num's goals.

A Structured and iterative approach

The methodology was thus both structured and iterative: starting with site-led narratives, refining them through storytelling devices, and consolidating them through transdisciplinary group work and review. The result is a set of storylines that provide not just technical descriptions of NBS practices, but insights into their transformative potential and their contribution to the greater vision of trans4num.

3. Country storylines

3.1 Hungary NBS Site Story– Szigetköz Region

EXPOSITION

Assumptions

NBS practices, such as crop rotation, cover cropping, the use of plant biomass, and bio-based fertilisers, has the potential to enhance the circularity of biological nutrient flows. They improve nutrient retention in soils and the recycling of organic matter while reducing dependence on synthetic fertilisers and chemicals.

By integrating these practices into farming systems, NBS can strengthen the role of soils as both nutrient sinks and buffers, supporting the development of regionally adapted and closed-loop regimes where dominant practices, technologies, and institutions contribute to managing nutrients in alignment with local climate, biodiversity, and food system priorities.

NBS hence act as levers for transformative change in agriculture, connecting soil, plant, animal, and human health, thereby promoting agricultural productivity, environmental sustainability and the resilience of food systems.

RISING ACTION

NBS practices are being tested on a 20-hectare experimental site, involving:

- 3-year crop rotation of durum wheat, sorghum, and soya to enhance soil biodiversity and reduce pest pressure.
- No-tillage farming, minimising herbicides and pesticides to protect soil structure and increase biological activity.
- Using bio-fertilisers (e.g., poultry manure) to improve fertility under environmental stress.
- Cover cropping and mulching over winter to retain moisture and sequester carbon.
- Sensor-based soil quality assessments to precisely capture soil carbon, moisture, and nitrogen in time.
- Monitoring systems using NDVI, drones, and satellite imagery to assess plant and soil health.
- Development of educational materials and decision-support tools, with active involvement of academic institutions and local stakeholders.

CLIMAX

The Szigetköz region in northwestern Hungary is a unique area with significant natural, economic, and social assets, while also facing several challenges.

In terms of natural and environmental conditions, Szigetköz is the largest inland delta in Central Europe, rich in biodiversity, with floodplain forests, wetlands, and backwaters. Much of the area is protected under the Natura 2000 network due to its ecological value. Climate change and invasive species further threaten the environment, though ecological restoration and the development of ecotourism present important opportunities.

Economically, the region is primarily agricultural, with fertile land supporting crop production and horticulture. Its location near the Austrian and Slovak borders offers advantages for trade and mobility. Still, the local economy is dominated by small-scale farms, an ageing agricultural workforce, and low-value-added production. There is considerable potential in adopting precision agriculture, developing local food processing, and promoting agro-tourism, especially through EU rural development funding.

Socially, Szigetköz is characterised by small villages with strong local identities and traditions. The area operates under multiple layers of governance, including local municipalities, national authorities, and EU frameworks. Water management and cross-border issues remain sensitive. However, the population is ageing, and younger generations often leave for urban areas or abroad. Access to essential services like healthcare and education is limited in many settlements. Yet, community cohesion, local cultural heritage, and digital solutions, such as remote work, offer pathways to improve the quality of life and retain the population.

Politically and institutionally, Fragmented governance can hinder coordinated development, but EU cooperation programs (such as INTERREG) and locally driven planning processes can strengthen institutional capacity and foster integrated development.

Overall, Szigetköz faces environmental degradation, demographic shifts, and economic limitations, but also holds significant opportunities for sustainable development through innovation, cooperation, and the responsible use of its natural and cultural assets.

FALLING ACTION

Outputs

The case study will provide practical and farmer-ready guidance on crop rotations and organic inputs, refined and scalable tools for environmental and agricultural monitoring in similar regions, decision support systems to support farm-level decision making, especially for ageing farmers and small operators, and open-source and interactive educational resources for knowledge transfer to students, farmers and advisors.

RESOLUTION

Expected outcomes in the trial field

A medium impact is anticipated in the short term, with improved soil structure and increased organic matter, resilient crop yields and balanced nutrient flows, enhanced biodiversity and soil biological activity, and measurable reductions in CO_2 emissions through no-tillage and organic fertilisers.

Expected outcome in the region

The expected outcomes of the NBS implementation in the Szigetköz region include improved nutrient and water management, enhanced biodiversity, increased climate resilience, and a shift toward more sustainable, low-input agricultural practices. These changes aim to strengthen local food systems, support rural livelihoods, and reduce the environmental impact of farming. In addition, increased stakeholder engagement and knowledge transfer will empower local actors and promote wider adoption of NBS across similar regions. The significance of these outcomes is considered medium to high: medium in the initial phase, as changes will benefit local communities and ecosystems with measurable improvements; and high in the longer term, given the potential for scaling successful practices nationally and even internationally, contributing to systemic environmental and agricultural transformation.

Vision

The long-term goal is to support a transition to climate-resilient and low-input farming systems through informed decision-making, community collaboration, and the widespread adoption of NBS practices in the Szigetköz region and beyond. By integrating nature-based solutions—such as sustainable nutrient and water management, biodiversity-enhancing land use, and soil restoration—into local farming, the interventions will directly address regional challenges like climate stress, water imbalance, and biodiversity decline, while also leveraging opportunities such as strong local agricultural traditions, institutional engagement, and rising demand for sustainable food systems.

This vision aligns closely with broader transformation goals set out in the Common Agricultural Policy (CAP), the EU Green Deal, and national rural development strategies. It contributes to enhancing agricultural productivity in an ecologically sound manner, promoting environmental sustainability, and strengthening the resilience of food systems. Through active stakeholder involvement and the transfer of knowledge and best practices, the Szigetköz site aims to serve as a scalable model for agroecological transition across Hungary and similar regions in Europe.

3.2 Denmark NBS Site – Limfjord Catchment

1. The Challenge of nitrogen in the Limfjord

Exposition – Setting the stage

In the Limfjord catchment, one of Denmark's most environmentally stressed regions, the story begins with a pressing challenge. Farmers are required to reduce nitrogen losses by 1,500 tons annually—a mandate, not an option—anchored in the EU Water Framework Directive and reinforced by Denmark's 2024 Green Tripartite Agreement (GTA). The GTA is ambitious: it seeks to deliver cleaner water, stronger biodiversity, and climate action, while also keeping rural economies alive. But the landscape around the Limfjord is complex. It is dominated by intensive farming, mostly livestock and mixed farming systems, and the soils vary widely in their capacity to retain nitrogen. For some farmers, land has been in families for generations, shaping not only economic decisions but cultural identity. The risk is clear: without alternatives, nitrogen cuts could mean economic disruption, a shrinking farm sector, and reduced food production. For farmers, these rules are not abstract numbers but real pressures on their income, their land, and their ability to pass farms on to the next generation. Yet, hidden in this tension lies an opportunity, to test whether Nature-based Solutions (NBS) can meet environmental goals without dismantling the very communities that depend on the land.

Innovating on the ground: Farmers, industry, and science

Rising Action – Characters and interventions

At the heart of the Danish site are three stakeholder groups, each carrying a piece of the story. Farmers are the frontline characters, balancing tradition, inheritance, and innovation. Many are ready to adapt, but they look for markets and policies that give them security. Industries and cooperatives are the second group, crucial for scaling but cautious without clear demand signals or regulatory stability. Scientists, policymakers and the local facilitator Climate Foundation Skive form the third group, designing models, testing frameworks, and reshaping rules to make change possible.

Together, these groups are testing one main intervention: circular crop rotations with perennial biomass crops, particularly grass and grass-clover. These systems keep living roots in the soil year-round, reducing nitrate leaching, improving soil health, and producing green biomass for biorefineries. In the biorefineries, proteins can be extracted for animal and human use, while residues such as brown juice and pulp are processed through biogas plants to create bio-based fertilisers that can substitute costly synthetic inputs.

Supporting these measures are tools and collaborations that enhance the initiative: remote sensing and nutrient-flow modelling with Cordulus, a regulatory sandbox established with four ministries and Climate Foundation Skive to test flexible rules, and structured engagement that brings farmers, advisors, regulators, and cooperatives into the same conversation.

At the crossroads: Balancing economy, culture, and policy - *Climax – Confronting the tensions*

As the experiments unfold, deeper tensions are revealed. Economically, supply and demand are the decisive forces. Farmers cannot risk adopting perennial rotations without guaranteed outlets for their biomass, and industries will not invest without assurance of supply and supportive regulation. Socially, farming is not just about yields but about identity. For many families, land is an inheritance, keeping them tied to traditional practices and slowing the pace of change. Even the meaning of “sustainability” is contested: for some it means low-intensity farming, for others it means advanced bioeconomy systems that circulate nutrients through high-tech processes. Policy adds its own challenges. The GTA and EU CAP bring obligations, but uncertainty remains over enforcement and whether early adopters will be rewarded. These tensions expose the limits of technical fixes. What is needed is not only better crops and fertilisers but alignment between policy, markets, and cultural values. The transformation will only succeed if all three move together, and if knowledge and needs from all three perspectives are taken into consideration.

Falling action – Early results

Despite these hurdles, the Danish site has begun to show momentum. New nutrient-flow models provide transparent, near real-time views of nitrogen flows under different rotations and fertilisation scenarios. Pilot farms are already demonstrating that perennial rotations can reduce nitrogen losses and still deliver biomass, working on real soils under real conditions, with results documented by scientists together with farmers. Stakeholder engagement has created dialogue platforms, helping to build trust where scepticism once prevailed. Links to green energy sectors — ethanol, e-methanol, and biogas — are beginning to anchor the value of perennial biomass. Meanwhile, the regulatory sandbox is testing flexible frameworks, offering ministries and regulators a way to learn alongside farmers and industries instead of dictating from afar.

Early wins and emerging insights - *Resolution – Vision and next steps*

From these efforts emerges a vision of climate-resilient, circular farming. In this vision, nitrogen losses are reduced to levels that protect the Limfjord, Denmark lowers its dependence on imported fertilisers, and food production is sustained even as farmland contracts.

Nutrient supply and demand are balanced regionally, creating a system where food, feed, and energy are integrated rather than competing. Engagement and transparency are vital to create clarity and shared understanding, but these also need to be coupled with well-designed incentive schemes and regulatory frameworks that reduce risks for early adopters and make participation attractive. The socio-ecological context matters deeply, demanding tailored solutions for different soils and landscapes. And though integrating environmental and socio-economic data is complex, it is indispensable for making robust, actionable decisions. The vision is one of farming that remains productive while protecting the Limfjord — where families can stay on the land, fertiliser imports are reduced, and the waters are safeguarded for generations to come.

Looking ahead to autumn and winter 2025, the Danish site will submit its storyline and deliverables while feeding findings into national policy debates. Efforts will focus on strengthening the voices of farmers and biorefineries within the trans4num framework. These next steps will deepen integration between science and practice, enhance policy relevance, and prepare the way for scaling NBS across Denmark's agricultural landscapes.

2. Storyline: Grass as the hero

Once upon a time in the Limfjord - *Exposition*

In the Limfjord catchment, the waters are suffocating under the weight of nitrogen. Every year, 1,500 tons must be removed if the fjord is to breathe freely again. The pressure is immense: farmers are asked to change the way they cultivate their land, industries are searching for solutions, and policymakers are writing ever-stricter rules. It is a battle for the future of both land, water and farming. Into this landscape grows Grass. Not just any crop, but perennial green crops that stay rooted year after year. Grass is our unlikely hero — steady, resilient, and quietly capable of doing what annual crops cannot.

Grass steps forward

Rising action

Grass understands the mission: to rescue the water environment — imagined here as the princess — from the villain Nitrogen, whose unchecked leaching poisons streams, rivers, and the Limfjord itself. But Grass cannot face this enemy alone. Along the journey, a fellowship of helpers appears. Scientists join, designing new cropping systems and models to reveal Grass's hidden strengths. Technologists arrive, creating machines and biorefineries that can turn Grass into protein, fertilisers, and energy. Policymakers supported by the Climate Foundation Skive test regulations in sandboxes, trying to build bridges instead of barriers. Farmers bring their land, their knowledge, and their courage to test new rotations. And industries and cooperatives begin to explore markets for the many gifts that Grass can provide. Together, these allies arm Grass with the tools needed to confront the challenge: knowledge about soil and water, machinery for harvesting and processing, economic models showing business opportunities, and the trust and engagement that hold a coalition together.

The great obstacles

Climax

The journey is far from straightforward. Grass soon encounters a wide divide — the gap between research and practice. Crossing it requires more than good intentions. New cultivation systems must be tested in the field and clearly explained. Transparent models must be developed so that farmers can see and trust the effects on their land. Regulation must adapt to enable adoption rather than slow it down. New technologies for extracting protein must prove not only functional but profitable. Farmers need to be convinced that the business case is real, and improvements to water quality must be documented in ways that society can recognise and value. Only by assembling all these pieces can Grass move from experimental plots to a mainstream solution in Danish agriculture.

Victories along the way

Falling action

Despite the obstacles, Grass and its helpers are already making progress. Pilot farms have demonstrated that perennial rotations can indeed reduce nitrogen losses while producing biomass for new uses. New value chains are beginning to connect Grass to biogas, bio-based fertilisers, and even green energy markets. Policy dialogues are underway, exploring more flexible rules that allow Grass to thrive. Tools such as those developed by Cordulus are helping to make nutrient flows visible, transparent, and trustworthy for all stakeholders. To support and accelerate bridging the gap from research to practice, Climate Foundation Skive facilitates knowledge sharing between helpers and stakeholders when needed. Each of these steps brings Grass closer to defeating Nitrogen and freeing the waters of the Limfjord.

A future with grass

Resolution

If the journey succeeds, Grass will not only save the princess — the water environment — but also create a new kingdom of circular farming. Across Denmark, fields of perennial crops will protect soils and waters, farmers will earn from both food and bio-based products, and the country will reduce its reliance on imported fertilisers. Local jobs will be created in green biorefineries and energy sectors, and Denmark will show Europe how agriculture, environment, and economy can thrive together. Grass, once seen as ordinary, will be recognised as the quiet hero of a new story — one where farming and nature work not against each other, but side by side.

3. Danish NBS Site – Policy Storyline (September 2025)

The Limfjord catchment is under some of the strictest environmental obligations in Denmark. Here, farmers are collectively required to reduce nitrogen losses to the aquatic environment by 1,500 tons per year. This is not a reduction in fertiliser inputs per se, but a target for lowering the amount of nitrogen that leaches from fields into streams, lakes, and fjords. The obligation stems from the EU Water Framework Directive and is reinforced by Denmark's

2024 Green Tripartite Agreement. Meeting this goal will require significant changes in land use and management, with far-reaching consequences for farming practices, rural economies, and water quality.

To meet this challenge, a set of Nature-based Solutions (NBS) is being tested, each designed to balance environmental goals with economic realities. At the core are perennial biomass rotations with grass and grass-clover. These systems reduce nitrate leaching, improve soils, and create a steady supply of biomass for green biorefineries. Complementing them are bio-based fertilisers derived from biorefinery residues such as brown juice and pulp, often processed through biogas plants. These fertilisers aim to replace synthetic imports and secure more closed nutrient cycles within the region.

Supporting measures strengthen the transition. Remote sensing and nutrient-flow modelling, carried out by Cordulus and Aarhus University, provide near real-time tracking of environmental outcomes. A regulatory sandbox involving four ministries supported by Climate Foundation Skive offers a space to test policies and adjust them in step with field results. These efforts bring science, practice, and governance into dialogue.

But tensions remain. Economically, circular farming will only take hold if secure markets exist for biomass and fertilisers. Socially, inheritance and farming traditions often slow change, while different visions of what counts as “sustainable” farming create uncertainty. Policy itself adds to the tension. CAP 13 and the Green Tripartite Agreement create obligations but leave open how enforcement will work and whether innovators will be rewarded.

Even so, early achievements are promising. Pilot farms are showing that perennial rotations can work in practice. Dynamic nutrient models are producing new insights. Stakeholder platforms are taking shape, feeding into early policy briefs, and links are emerging to green energy sectors such as ethanol, e-methanol, and biogas.

The vision is of a climate-resilient, circular agricultural system that maintains food production while reducing nitrogen losses. It is a system that aligns local farming with CAP objectives and the EU Green Deal, offering a replicable model for Europe. The next steps focus on integrating diverse stakeholder perspectives, strengthening regulatory pathways, and co-developing scalable models for food–nutrient–energy systems that can move from pilot projects to national strategies.

3.3 UK NBS Site – Devon (Novel P-based Fertiliser)

Reality

The growth of crops at rates of production required to feed an expanding human population is reliant on four macronutrients: nitrogen (N), phosphorus (P), potassium (K) and sulphur (S). Should any single nutrient be limited, then plant growth is reduced to a fraction of its potential, affecting rates of food production.

The majority of phosphorus-based fertilisers are manufactured from a rock phosphate raw material. Global production of rock phosphate is concentrated in a small number of locations with difficult geo-political sensitivities present therein, such as the Western Sahara region of Morocco, where conflict between separatists and government agencies exists, and China, where export of rock phosphate is restricted. Should a situation arise where the export of rock phosphate is no longer possible, then global stocks of P-based fertilisers will rapidly be consumed. This would leave a shortfall in the ability of farmers to continue to produce food at rates of production the global food supply-chain has become accustomed to.

Alternative methods of producing phosphorus-based fertilisers are available and include the recycling of material that is rich in phosphate compounds. One such example is the use of bone material - a byproduct of the abattoir industry largely made up of apatite (a compound rich in calcium phosphate). Through a chemical transformation, the phosphorus found within the apatite is made available to plant roots and thus can be used as a phosphorus-based crop fertiliser. This phosphorus-based fertiliser has been named Thallo by the company Elemental Ltd, which is developing this product.

One beneficial side effect of using recycled bone material instead of rock phosphate-based fertilisers is the avoidance of a potentially toxic build-up of cadmium, a heavy metal element commonly found within rock phosphate deposits.

Inputs

A replicated block field trial is taking place at the Rothamsted Research North Wyke site in Devon, using two cropping systems: 1) an arable crop and 2) a grass silage crop. Inputs are based on U.K. national fertiliser recommendations and are balanced for N, P, K & S.

Outputs

A positive control using the standard fertiliser produced from rock phosphate (triple super phosphate) and a standard nil control will be used to test the potential of the abattoir byproduct phosphorus-based fertiliser to produce crops. Nutrient density within the harvested crops will also allow an investigation into the efficacy of the novel P fertiliser to provide micro-nutrients required for a healthy diet. Elements such as zinc, manganese and copper are contained within the Thallo fertiliser, but are absent from standard NPKS fertilisers usually used on farms.

Outcomes

The results from the trials on the use of Thallo fertiliser for the production of two different crops in Devon will be used to demonstrate the efficacy of this fertiliser. This will allow a new industry to be developed where farmers are no longer reliant on the production of rock phosphate-based fertilisers.

Vision

A shift away from relying on sensitive geopolitical areas for one of the foundations upon which modern agricultural food production is based will allow for a more resilient nutrient production system to be developed. This has the potential to safeguard food production against (geo-)political developments that may restrict access to rock phosphate deposits in the future.

Income generation for farmers may also increase if farmers can valorise not only the meat, hide and fat of the animal, but also valorise the bone material from domestic livestock, should it be used as a key phosphorus fertiliser input into the food production system. This may allow farmers to increase the likelihood of being able to maintain a livelihood from farming and producing food.

Key insights gained

At a research insights open day, several farmers visited the replicated plot field trial based at the North Wyke site and commented on what the crop looked like during the very early stages of its growth in the spring of 2023. Unfortunately, a drought ensued through the remainder of the spring, and crop production was severely affected by low soil water availability.

Next Steps (summer and autumn 2025)

A new replicated plot design on winter wheat and ryegrass forage crop has been set up, and applications of the fertilisers have been made. Harvesting of the first cut of grass has been made, and future harvests are planned for the remainder of 2025 and in 2026. The winter wheat arable crop has also received a number of fertiliser applications, and crop growth is developing well, with a harvest planned for late summer 2025, and another arable crop planned for 2026.

3.4 UK NBS Site – Rothamsted LSRE (Compost & Rotations)

Your magical green* bin…

Introduction

*Commonly, garden and kitchen waste bins are green, but they may come in different colours.

(Covers Exposition on story arc and introduces Rothamsted, compost, and farmers as characters)

On many weekends across the United Kingdom, many people will spend time in their gardens. The desire for clean and manicured lawns and borders, well-kept trees and managed bushes and shrubs calls for a high level of maintenance. This maintenance of gardens also creates a vast amount of green waste, lawn clippings, tree branches, flowers, etc. Not only that, but green waste produced by UK households will often also include kitchen food waste, anything from eggshells, pet food and plate scrapings. Waste from day-to-day human activity has the potential to be recycled and used to further aid other areas of society that we don't always consider. At the same time this waste is being produced, farmers are looking for ways to grow their crops in an increasingly unpredictable climate. Could adding composted waste from gardens and households to fields be part of the solution to making farming more resilient?

This is precisely what scientists at Rothamsted Research have been looking at. Rothamsted has, for 180 years, been investigating these problems. How can science and innovation make society better? The origins of Rothamsted science are in the invention of fertilisers that have since largely replaced inputs of manure and compost to feed crops. However, we now know that those ‘organic’ inputs add more to the soil than just nutrients. They improve ecosystems, biodiversity, and strengthen food chains and build resilience against climate change; however, these benefits are often only observed over long time scales.

Rothamsted has a reputation for taking a long-term approach to solving problems and is world-renowned for the longest agriculture experiment, Broadbalk. It was with this mindset of scientific excellence and willingness to experiment over the long term that the Large-Scale Rotation Experiment (LSRE) was created. Rothamsted’s scientists want to know the different ways nature-based agriculture practices (including adding compost) can change the way we farm for the better. How do farmers overcome the challenges of reduced yields and potential increases in pest, weed, and disease pressure that often follow a movement to these more sustainable ways of farming?

The hero of our story is the LSRE and its innovative uses and arrangements of nature-based agricultural practices. This isn’t just about compost working for crops; it’s how it does it and what combinations and rotations of different crops and other methods can give farmers the best outcomes for their farm. These measures and the knowledge gained from the LSRE support more resilient farming and strengthen food systems and food security. Issues that are pertinent not just to farmers but to everyone.

The LSRE

(covers rising action on the story arc and setting from story elements)

When farmers apply fertilisers from a bag to crops, the benefits are short-term and predictable. However, though most farmers would agree that adding compost is a good thing, the benefits are often cumulative and difficult to quantify in the short term. As there is also a cost involved in buying and transporting the compost, farmers need evidence to support the decision to add it to their fields. Collecting and communicating this evidence is often complicated because it depends on the environment (soils and weather) and other decisions that the farmer makes, like how they cultivate their soil.

The LSRE was set up to provide this long-term evidence for the benefit of compost and other nature-based solutions. The experiment is at two sites, so we can see if the effect of the compost differs between soil types and local weather. It also tests the benefit of compost for different crops grown in rotations (sequences of crops) where the soils are either ploughed or left undisturbed, and with different approaches to controlling pests, weeds and diseases. By testing the soil and monitoring the biodiversity in the experiment, Rothamsted scientists can tell not only how compost can support yields but also how it can improve the resilience of the whole farm.

Creating circularity and mitigating risk.

(covers climax/results and feeds into analysis of data (falling action) from the story arc/ challenges and characters are present from the story elements)

The happiness found in our story is the way that Rothamsted scientists are finding ways to create circular processes, making use of organic waste to bring health and resilience to crops.

After all, those crusts of bread that your toddler has decided against eating came from the field. Using organic inputs, like compost, means that farmers can now have a better understanding of how not clearing a plate after lunch or dinner can improve and secure their next dinner. Returning nutrients to the ground from kitchen waste or from garden waste helps support plant growth and takes farming and society another step along the way to more sustainable living, so that when your toddler has a toddler, they will have security in their food system and a healthier planet.

But it is not just about the nutrients that the compost provides; the LSRE is also revealing additional benefits for soil health. Specifically, we are seeing the amount of carbon in the soil building up where compost is added. This is important because farmers are under pressure to reduce their carbon footprint. If fertilisers could also be reduced in the fields where compost is added, this would also reduce the amount of greenhouse gases that are released in the process of crop production. As well as contributing to the environmental sustainability of the farm, this could also help achieve economic sustainability, as improving soil health can be supported by government subsidy schemes.

For farmers, these changes bring with them inherent challenges and concerns. Farming is not just an occupation but a way of life, a tradition, and a generational practice that is often passed down through the generations. Many farmers, regardless of their approach, see their role in society as one of stewardship of the land. However, it’s important to remember that they are also livelihoods, and any changes to how farmers practice their work bring with them risk. These social and economic tensions are currently colliding with environmental tensions, with the need to find more sustainable practices. Not just for planetary health but also to improve the farmers' outcomes. Crops are being destroyed by pests, weeds, diseases, and unpredictable weather due to climate change. The LSRE is producing the knowledge for farmers to be able to confidently tackle these tensions. The work of Rothamsted and the LSRE experiment is there to try and help farmers mitigate the risks of change, but also to guidehow to overcome these tensions to enable them to overcome those challenges.

The LSRE Resolution.

Because the benefits of adding compost depend on the local environment and other decisions the farmer makes, a farmer cannot directly take the results from the LSRE and assume they will see the same effect. There will always need to be some interpretation. The LSRE has purposefully been designed with this flexibility in mind, but making the results relevant and useful requires additional steps and actors to be involved (Figure 1).

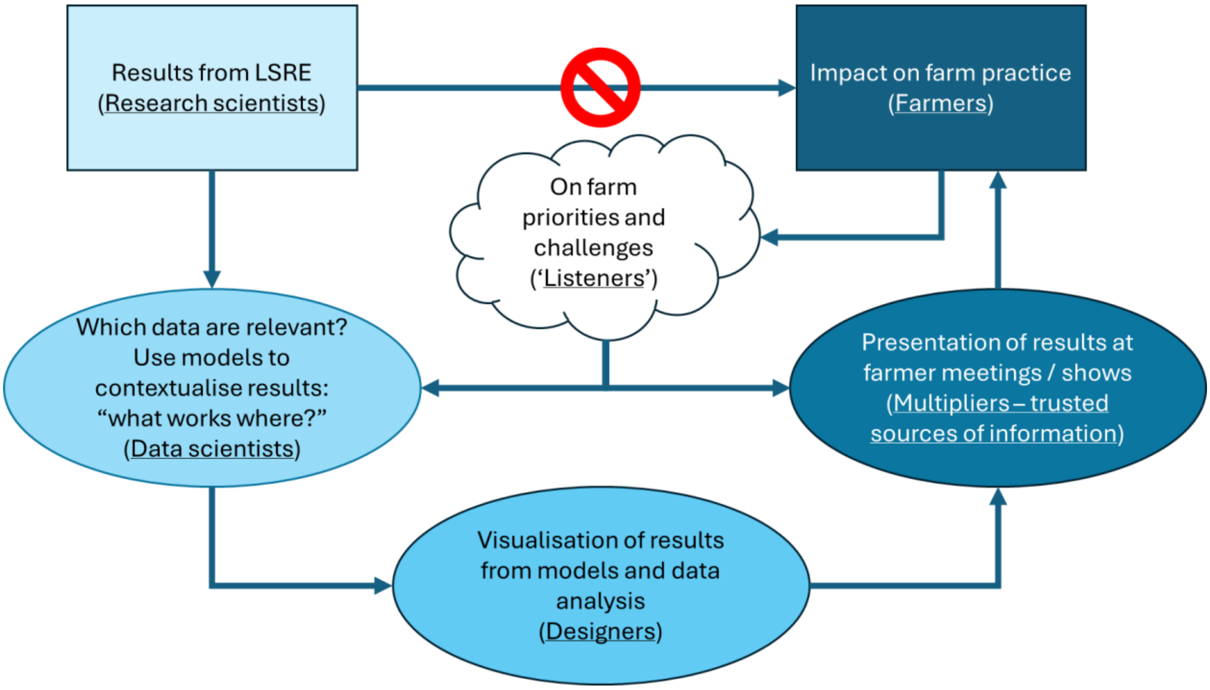


Figure 1 Delivering impact from the results of LSRE using the idea of 'alternative storylines.
To assume that demonstrating the results of the LSRE to farmers directly will result in a change in practice is naïve. Rather, the findings of the LSRE need to be interpreted in the context of and tailored to the specific priorities and challenges of farmers. Listening to this input is the first step to making the results relevant and useful. However, additional steps are then required to make the data available in a way that is appropriate to the specific audience and questions raised. This will require the input from additional actors, including data scientists, graphic designers and the trusted sources of information for farmers.

3.5 Netherlands NBS Site – Plant-based nutrition

How it started.

Along the Northern coast of the Netherlands, in the provinces of Groningen and Fryslân, lies the 'Noordelijke bouwhoek'. A polder area bordering the vulnerable N2000 nature reserves, such as the Wadden Sea (World Heritage) and the Lauwersmeer area. This area consists of fertile sandy and clay soils and is the cradle of seed potato production. Almost all arable farms in the region are specialised in this crop. The research site SPNA-Kollumerwaard is located in the centre of this seed potato area.

In 2011, a group of organic arable farmers from this area came up with the idea of investigating whether it would be possible to stop adding nitrogen to the soil as part of the nutrition of their crop rotation plan and instead grow all the nitrogen required by their crops themselves as part of their cultivation plan. This idea was translated into a multi-year system study on 7 hectares, in which no nutrients were supplied from outside the cultivation plan in the crop rotation plan, which included cash crops.

'Planty Organic' was born. A cultivation system based purely on plant-based fertilisation. This initial research was completed several years ago, but the project is still ongoing, and only plant-based fertilisation is used.

Why plant-based fertilisation?

To understand this, we need to look at the specific conditions in the Netherlands under which organic farming is practised. In the Netherlands, there are mainly specialised organic arable farms that do not keep livestock themselves. In organic farming, the main source of nutrients is animal manure. So, without animals on the farm, all animal manure has to be bought from organic livestock farmers who don't need this for their own soils. But there is a structural shortage of organic manure, and the prices are high. This is an economic factor that makes research into other sources of fertilisation attractive. Plant-based sources of fertilisation are an obvious choice.

In addition, there is a growing social awareness of the need to recirculate plant-based organic waste streams from society and return them to the place where minerals can actually be reused: on agricultural soils. In fact, the soil is the only place where the recirculation of minerals can take place.

A quite new argument is that crops fertilised exclusively with plant-based fertilisers may serve a new market for consumers who want to live a completely vegan lifestyle.

Tool

There are many factors that play a role in the availability of nitrogen to plants. In order to gain a clear picture of this and also to take into account the effects of, for example, previous crops and green manure/cover crops, the NDICEA model is used in experiments on plant-based fertilisation. This model provides more insight into the nitrogen balance of the specific plot and the supply-demand ratio for the specific crop.

Challenges

Practical research into plant-based fertilisation has taught us that a fertilisation strategy consisting exclusively of plant-based fertilisation presents certain challenges. The most important one concerns the timing of the nitrogen availability.

In particular, the nitrogen availability from plant-based fertilisation does not run parallel to the plant's needs. In the spring, the mineralisation of soil that is only fed with plant-based fertiliser is unable to sufficiently meet the needs of the crop. After this initial phase, the system works quite well, but the initial deficit is not made up for in most crops. This leads to suboptimal yields for the most important consumer crops. It is difficult to solve this challenge because it has a lot to do with the lack of activity of the microorganisms in the soil in the spring. The soil temperature is mostly too low.

But the combination of plant-based nutrition and another (faster) nitrogen source in the spring can offer a better perspective.

Next phase

Based on the knowledge and experience gained from the practical use of plant-based flows as fertiliser, within T4N, we have started various field trials. Two examples: In field trials in conventional arable farming, we have replaced a part of the nitrogen fertilisation in cereal cultivation with plant-based fertilisation. (pellets of alfalfa or grass-clover). In this way, we replace a part of the input from artificial fertiliser and make the cultivation of cereals more circular.

In addition, we have started a study to investigate under which circumstances a good cover crop can meet the entire nitrogen requirement of a seed potato crop. Why seed potatoes? In the northern clay region, the cultivation of seed potatoes is by far the most important crop for arable farming. It is also a crop that requires relatively little nitrogen because it has a short growing season.

NBS as a vision for Agrofuture

At SPNA, we are working on future-proof and sustainable arable farming, in which unnatural inputs are minimised. NBS approaches are absolutely essential in this regard. Within T4N, the emphasis is on nutrient supply, but there are also major challenges in the area of crop protection. Ultimately, this will lead to a system change within conventional arable farming. Within our long-term ‘Agrifuture’ project, in which we have now developed and implemented such a cultivation system, NBS is an important basis for cultivation decisions. The knowledge we gain through T4N is one of the elements we need for developing this future farming system.

Connection to the sector

As in 2011, we are not doing this alone. Only when it works in practice will a system change lead to success. In this way, we connect science and practice. Besides scientific knowledge, we have invited arable farmers from our area to contribute their ideas about practical opportunities.

But during the daily practice, we want a connection. During the growing seasons, there are many decision moments a grower has to take regarding fertilisation, crop protection and other cultivation actions. In fact, at each decision moment, a choice has to be made: do I intervene and if so, how? To ensure this process runs smoothly, an experienced but “traditional” crop consultant looks on.

In this way, at every important cultivation decision, the trade-off is made between the “common best practice” way of working and alternatives determined from the NBS approach. This connection with current practice also provides additional involvement from the advisory world and thus an extra bridge to daily arable practice.

4. Cross-country analysis

While each site operates in a distinct environmental, social, and policy context, several common themes emerge when comparing the storylines.

Implementation approaches differ but share a circular logic.

- In Hungary, the emphasis is on crop rotations, no-till, and cover cropping to enhance soil biodiversity and nutrient retention.
- In Denmark, perennial grasses and bio-based fertilisers from biorefineries are being tested to reduce nitrogen leaching and close nutrient loops.
- In the UK, two approaches are explored: long-term compost application in rotations (Rothamsted LSRE) and the use of a novel phosphorus fertiliser derived from abattoir by-products (Devon).
- In the Netherlands, the focus is on plant-based fertilisation, building on the long-term "Planty Organic" system and testing new uses of plant-based nutrient flows (e.g. alfalfa pellets, grass-clover, and cover crops in seed potato systems). These trials aim to reduce reliance on external inputs such as animal manure and synthetic fertilisers, while exploring new consumer markets (e.g. vegan-labelled crops).

Evaluation activities combine field experimentation with stakeholder engagement.

All sites rely on replicated trials, monitoring tools (sensors, drones, models), and participatory workshops to assess impacts. These activities ensure that the results are not only scientifically valid but also socially grounded and policy-relevant.

Tensions are a recurring feature across sites.

- In the Netherlands, the NDICEA model is used to track nitrogen balances and the timing of nutrient availability. Farmers and advisors are directly engaged in evaluating whether plant-based fertilisation can be integrated into standard practices, ensuring strong science–practice connections.
- **Policy tensions:** strict nutrient reduction targets (Denmark), fragmented governance (Hungary), evolving CAP implementation (all sites), and the challenge in the Netherlands of aligning plant-based fertilisation strategies with existing regulations on manure use and nutrient application.
- **Social tensions:** inheritance and tradition slowing change (Denmark, Hungary); farmers' risk aversion to new practices (UK); ageing populations (Hungary); and in the Netherlands, balancing the drive for innovation with the realities of advisory practices and conventional "best practice" norms.
- **Economic tensions:** viability of new value chains (Denmark), costs of compost (UK), market acceptance of bone-based fertiliser (UK Devon), and in the Netherlands, the high cost and limited availability of organic manure, which creates both a barrier and a driver for exploring plant-based fertilisation.

Shared outcomes and visions converge around circularity and resilience.

Across all sites, the emerging vision is one of circular nutrient management and reduced dependency on external inputs.

- **Hungary:** building resilient, low-input systems that improve soils and biodiversity.
- **Denmark:** demonstrating perennial biomass systems and nutrient cycling through bio-based fertilisers.
- **UK:** showing how compost and waste-derived fertilisers can secure nutrient supply and strengthen soil carbon.
- **Netherlands:** advancing plant-based fertilisation as a pathway to future-proof arable systems, reducing reliance on manure and synthetic fertilisers while aligning with consumer and societal demands for sustainability.

Together, the sites point towards common outcomes:

- Reduced dependency on external fertilisers and geopolitical supply risks.
- Improved soil health, biodiversity, and water quality.
- Maintenance of food production alongside environmental goals.
- Creation of new value chains linking agriculture to bio-based industries.

Linking to European goals

Despite differences in practice, all sites demonstrate how local experimentation can be linked to wider European objectives: the EU Green Deal, CAP reform, climate and biodiversity targets, and the search for resilient food–nutrient–energy systems. Overview of Nature-Based Solution Interventions and Key Socio-Ecological Tensions Across European Agricultural Sites

Table 1. Overview of Nature-Based Solution Interventions and Key Socio-Ecological Tensions Across European Agricultural Sites

Country / Site	Focus & Setting	Main NBS Intervention(s)	Key Tensions Identified
Hungary (Szigetköz)	Inland delta, Natura 2000 area, small-scale farms, ageing workforce	Crop rotations (durum wheat, sorghum, soya), no-till, cover crops, bio-fertilisers, drone & sensor-based monitoring	**Policy:** fragmented governance; **Social:** aging population & outmigration; **Economic:** low value-added production
Denmark (Limfjord)	High nutrient reduction targets (1,500 tons N), intensive farming	Perennial biomass rotations (grass, grass-clover); bio-based fertilisers from biorefineries; policy sandbox	**Policy:** CAP & Green Tripartite obligations; **Social:** inheritance & traditions; **Economic:** lack of secure biomass markets

UK (Rothamsted LSRE)	Long-term experiment on compost use across rotations	Application of composted garden/food waste; monitoring soil carbon & biodiversity	**Social:** farmers' risk aversion; **Economic:** transport & application costs; **Policy:** evidence required for subsidy alignment
UK (Devon)	Reliance on imported rock phosphate fertiliser	Thallo fertiliser from abattoir bone material; replicated trials in arable & silage crops	**Economic:** farmer acceptance & market development; **Policy:** regulatory approval; **Social:** perceptions of waste-based inputs
Netherlands (Planty Organic / SPNA)	Fertile polder soils, seed potato cradle, no livestock on arable farms	Plant-based fertilisation (cover crops, alfalfa/grass-clover pellets, NDICEA modelling); long-term trials	**Economic:** shortage & high cost of organic manure; **Social:** need to align with advisory practice; **Policy:** nutrient-use regulations

5. Conclusion and next steps

This second report on NBS case implementation shows that the project has progressed from planning and initial trials (as reported in D2.2) to substantive experimentation and transdisciplinary evaluation. Across Hungary, Denmark, the Netherlands, and the UK, the storylines document not only technical advances but also the economic, social, and policy tensions that condition the uptake of Nature-based Solutions (NBS).

A key conclusion is that NBS hold strong potential to address nutrient challenges in European agriculture, but their success depends on enabling conditions: supportive regulatory frameworks, viable markets and value chains, and sustained stakeholder engagement. Technical performance alone is not enough—transformation requires alignment across sectors and scales.

Several cross-cutting insights emerge:

Circularity is a shared ambition, with sites testing different pathways—from plant-based fertilisation in the Netherlands, to perennial rotations in Denmark, to compost and novel P-fertilisers in the UK, and crop diversification and monitoring in Hungary.

Tensions recur across sites, with policy obligations and uncertainties, economic risks and opportunities, and social traditions and perceptions shaping transitions.

Storytelling has proven an effective tool for integrating agronomic evidence with social and policy dimensions, making the sites' work more accessible to wider audiences.

Next steps for the project include:

Deepening evaluation in Year 3, with a stronger integration into the RIOOV framework.

Translating site findings into targeted policy briefs and dissemination materials for farmers, cooperatives, and regulators.

Advancing cross-site comparisons to identify generalisable lessons and scalable models.

Strengthening the link between experimental plots and broader transformation pathways in national and EU policy debates.

Together, the country reports demonstrate that experimentation at the field and farm level can generate both practical solutions and broader insights into how European agriculture might transition toward circular, resilient, and sustainable nutrient management.

Appendix 1- Storyline draft before GA workshop

NBS-site integrated storyline and progress report (May 2025)

NBS site - Denmark

a. Reality: The Danish NBS site is situated in the Limfjord catchment, a region facing some of the strictest nutrient reduction targets in Denmark. The area is under intense pressure to reduce nitrogen leaching into surface waters, with an obligation to cut nitrogen emissions by approximately 1,500 tons of nitrogen per year in the NBS site region alone. This is driven not only by the EU Water Framework Directive but also by Denmark's Green Tripartite Agreement—a binding national consensus between agricultural, environmental, and political actors that aims to meet climate, water quality and biodiversity goals while preserving the viability of rural economies.

Under the Green Tripartite Agreement, the Limfjord area is identified as one of the regions where significant land will have to be taken out of agricultural production, or converted into alternative uses like wetlands or forests. This has profound implications for farmers, local economies, and land-use planning.

The landscape is currently dominated by intensive farming, substantial variability in nitrogen retention capacity, soil types, and land-use intensity. Current farming practices must now adapt rapidly to align with national and EU-level environmental targets. However, without viable alternatives, the mandated reductions could lead to substantial economic disruption and a reduction in food production. This creates both a challenge and an opportunity for Nature-based Solutions (NBS) to demonstrate how environmental goals can be met without displacing farmers or undermining agricultural productivity.

b. Inputs

To promote circular nutrient management, the Danish NBS site is testing two key interventions:

1. Circular crop rotations using perennial biomass crops such as grass and grass-clover:
    - These rotations reduce nitrate leaching, improve soil structure, and supply green biomass for biorefinery applications that yield protein for monogastric animals, food protein and ruminant feed from residue pulp.
2. Bio-based fertilisers sourced from biorefinery residues such as brown juice and surplus pulp via biogas plants:
    - These fertilisers aim to close nutrient loops, reducing reliance on synthetic inputs and supporting a more resilient and localised nutrient economy.

Supporting activities include:

- Participatory stakeholder engagement, with interviews and planned workshops involving farmers, advisors, regulators, and industry.
- Remote sensing and modelling to track nutrient flows and evaluate environmental impacts in near-real time (e.g., through collaboration with Cordulus).

- Development of a regulatory sandbox in cooperation with four Danish ministries to test and adjust policy frameworks for NBS implementation (Klimafonden Skive).
- Substance-flow modelling led by Aarhus University to integrate nutrient variables for farm-level and regional planning.

c. Outputs

- A dynamic model of nutrient flows under different cropping and fertilisation scenarios.
- Stakeholder maps and engagement plans.
- Initial policy briefs and information materials targeted at municipalities, cooperatives, and regulators.
- Establishment of value chain links to green energy sectors (e.g., ethanol, e-methanol, biogas).

d. Outcomes

Short- to Mid-Term

- Reduced nitrogen leaching from vulnerable soils.
- Increased organic matter and biodiversity through perennial biomass systems.
- Greater awareness and engagement among local farmers and SMEs.
- Early adoption of NBS-supported rotations among pilot farms.

System-Level

- Formation of multi-actor coalitions exploring integrated NBS value chains.
- Cross-sector dialogue leading to initial consensus on scaling pathways and investment needs.
- Institutional learning about the regulatory and operational enablers needed to support NBS.

The expected impact level is medium to high, with strong potential for upscaling across Denmark's agricultural landscapes, particularly where biomass and nutrient losses are pressing concerns.

e. Vision

The Danish site envisions a future of climate-resilient, low-input farming, enabled by new food/feed value chains, circular nutrient management and robust innovation. Our long-term goal is to:

- Reduce Denmark's dependency on external fertiliser inputs.
- Reduce agricultural impacts on water bodies to an acceptable level.

- Maintain net food production volumes on a diminishing area.
- Synchronise nutrient supply and demand using regional biomass flows.
- Demonstrate a replicable model for integrated food-nutrient-energy systems, combining agriculture, green biorefinery, and waste valorisation.
- Align local practices with CAP objectives, the EU Green Deal, and Denmark's Climate Agreement for Agriculture.

Key insights gained

From the first project phase, several critical lessons have emerged:

- Stakeholder engagement is essential: Technical fixes alone are insufficient. Farmers must see both environmental and economic benefits to support widespread adoption.
- Farmers are incabable of action without simultaneous industrial action: Economically and regulatorily favourable conditions for industries are paramount for building new value chains.
- Context matters: High spatial variability in the Limfjord catchment demands tailored solutions—not one-size-fits-all blueprints.
- Tools work best when transparent and user-friendly: Cordulus tools and CFS models have helped local actors visualise NBS impacts, improving trust and engagement.
- Economic and ecological benefits are mutually reinforcing: Perennial rotations both cut nutrient losses and create valuable biomass streams, supporting new markets and local jobs.
- Data integration is complex but essential: The merging of environmental monitoring with socio-economic modelling is labour-intensive, but crucial for robust, actionable insights.

Next Steps (summer and autumn 2025)

- Submit the current storyline and documentation by 23rd May, activating content from Deliverables D1.2,1.3 and D1.4, D2.2, and existing stakeholder materials.
- Unfold inputs to regulatory priorities and changes to national level stakeholders, and analyse responses relevant for defining necessary actions for realising transformation pathways
- Support peer review and refinement of the RIOOV structure across the consortium in early June, with special attention to:
    - Farmer and biorefineries input, which has been underrepresented in earlier versions.

  - Ensuring site stories reflect the full range of socio-ecological dynamics, not just technical measures.
  - Helping social and natural scientists better understand how to co-develop site narratives depending on local conditions.

NBS site - Hungary

a. Reality: The Szigetköz region in northwestern Hungary is a unique area with significant natural, economic, and social assets, while also facing several challenges.

In terms of natural and environmental conditions, Szigetköz is the largest inland delta in Central Europe, rich in biodiversity, with floodplain forests, wetlands, and backwaters. Much of the area is protected under the Natura 2000 network due to its ecological value. Climate change and invasive species further threaten the environment, though ecological restoration and the development of ecotourism present important opportunities.
Economically, the region is primarily agricultural, with fertile land supporting crop production and horticulture. Its location near the Austrian and Slovak borders offers advantages for trade and mobility. Still, the local economy is dominated by small-scale farms, an ageing agricultural workforce, and low-value-added production. There is considerable potential in adopting precision agriculture, developing local food processing, and promoting agro-tourism, especially through EU rural development funding.
Socially, Szigetköz is characterised by small villages with strong local identities and traditions. However, the population is ageing, and younger generations often leave for urban areas or abroad. Access to essential services like healthcare and education is limited in many settlements. Yet, community cohesion, local cultural heritage, and digital solutions—such as remote work—offer pathways to improve quality of life and retain population.
Politically and institutionally, the area operates under multiple layers of governance, including local municipalities, national authorities, and EU frameworks. Water management and cross-border issues remain sensitive. Fragmented governance can hinder coordinated development, but EU cooperation programs (such as INTERREG) and locally driven planning processes can strengthen institutional capacity and foster integrated development.
Overall, Szigetköz faces environmental degradation, demographic shifts, and economic limitations, but also holds significant opportunities for sustainable development through innovation, cooperation, and the responsible use of its natural and cultural assets.

b. Inputs: NBS practices are being tested on a 20-hectare experimental site, involving:

- 3-year crop rotation of durum wheat, sorghum, and soya to enhance soil biodiversity and reduce pest pressure.
- No-tillage farming, minimising herbicides and pesticides to protect soil structure and increase biological activity.
- Using bio-fertilisers (e.g., poultry manure) to improve fertility under environmental stress.
- Cover cropping and mulching over winter to retain moisture and sequester carbon.

- Sensor-based soil quality assessments to precisely capture soil carbon, moisture, and nitrogen in time.
- Monitoring systems using NDVI, drones, and satellite imagery to assess plant and soil health.
- Development of educational materials and decision-support tools, with active involvement of academic institutions and local stakeholders.

c. Outputs: It will provide practical and farmer-ready guidance on crop rotations and organic inputs, refined and scalable tools for environmental and agricultural monitoring in similar regions, decision support systems to support farm-level decision making, especially for ageing farmers and small operators, and open-source and interactive educational resources for knowledge transfer to students, farmers and advisors.

d. Outcomes:

Expected outcomes in the trial field

A medium impact is anticipated in the short term, with improved soil structure and increased organic matter, resilient crop yields and balanced nutrient flows, enhanced biodiversity and soil biological activity, and measurable reductions in CO_2 emissions through no-tillage and organic fertilisers.

Expected outcome in the region

The expected outcomes of the Nature-Based Solutions (NBS) implementation in the Szigetköz region include improved nutrient and water management, enhanced biodiversity, increased climate resilience, and a shift toward more sustainable, low-input agricultural practices. These changes aim to strengthen local food systems, support rural livelihoods, and reduce the environmental impact of farming. In addition, increased stakeholder engagement and knowledge transfer will empower local actors and promote wider adoption of NBS across similar regions. The significance of these outcomes is considered medium to high: medium in the initial phase, as changes will benefit local communities and ecosystems with measurable improvements; and high in the longer term, given the potential for scaling successful practices nationally and even internationally, contributing to systemic environmental and agricultural transformation.

e. Vision: The long-term vision of the NBS site in Szigetköz is to create a resilient, sustainable agricultural landscape that harmonises high-yield food production with environmental conservation and climate adaptation. The long-term goal is to support a transition to climate-resilient and low-input farming systems through informed decision-making, community collaboration, and the widespread adoption of NBS practices in the Szigetköz region and beyond. By integrating nature-based solutions—such as sustainable nutrient and water management, biodiversity-enhancing land use, and soil restoration—into local farming, the interventions will directly address regional challenges like climate stress, water imbalance, and biodiversity decline, while also leveraging opportunities such as strong local agricultural traditions, institutional engagement, and rising demand for sustainable food systems.

This vision aligns closely with broader transformation goals set out in the Common Agricultural Policy (CAP), the EU Green Deal, and national rural development strategies. It contributes to enhancing agricultural productivity in an ecologically sound manner, promoting environmental sustainability, and strengthening the resilience of food systems. Through active stakeholder involvement and the transfer of knowledge and best practices, the Szigetköz site aims to serve as a scalable model for agroecological transition across Hungary and similar regions in Europe.

NBS site – the Netherlands

a. Reality: The Kollumerwaard is situated on sandy loam soil, a fertile type of soil suitable for a variety of crops. However, it is also susceptible to erosion and compaction, requiring careful management. The area borders the Lauwersmeer and is part of the Natura 2000 network, making it an important region for nature conservation and biodiversity. The main crop grown here is seed potatoes. In addition to conventional arable farming, organic agriculture is also widely practised in the region.

Ebelsheerd is located on heavy clay soil and is particularly known for its grain cultivation. There is a growing interest in sustainable and regenerative farming practices, which creates opportunities for developments related to nature-based solutions—approaches that harness natural processes to support agriculture, landscape management, and climate resilience.

The main Challenges and developments for both areas at this moment are:

Soil quality is under pressure due to intensive farming practices, leading to a loss of organic matter and a reduction of soil fertility.

Water Management, changes in precipitation patterns and water availability require adjustments in irrigation and drainage to maintain both agricultural productivity and ecological values.

An ageing farming population and a shortage of skilled workers pose challenges for continuity and innovation within the agricultural sector. The adoption of new sustainable practices depends on effective knowledge transfer and support for farmers.

The use of sensors, drones, and other technologies can support the monitoring of soil and crop conditions, enabling more efficient and sustainable land use.

b. Inputs:

Planty Organic; This research includes a cultivation plan based on the regular crops in this area: potatoes, pumpkins, carrots, grains and grass clover, but further supplemented with green manures. Unique is that during the first 10 years of this research, no minerals were supplied. No manure was supplied, and the harvested grass clover was used directly as fertiliser. (Cut and carry fertiliser) After this first period, the object continued with the supply of compost and bokassi. No animal manure or artificial fertiliser is still supplied in this system.

Conventional: Testing whether the standard fertilisation 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.

Seed potatoes: 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.

Stakeholder Engagement: Each season, multiple groups of farmers and advisors will visit the trial fields and evaluate the results during the winter season, in order to learn from the potential of the various Nature-Based Solutions (NBS)

c. Outputs:

Each year, statistically reliable results will be published in reports, which will include conclusions as well as recommendations for the application of Nature-Based Solutions (NBS). After four years of research, fact sheets will be developed and distributed to growers and advisors to ensure the widest possible dissemination of the findings. These results will serve as a guideline for adjusting conventional fertilisation practices in various crops towards NBS approaches, such as cut-and-carry systems or the use of organic pellets.

d. Outcomes:

The minimum outcome in the region is to inform farmers and advisors about the possibilities of alternative fertilisation methods and cropping systems. In addition to raising awareness, we expect that a large group of growers will begin to implement the Nature-Based Solutions (NBS) we have tested for them on their own farms. In the long term, we anticipate that this will spread widely and that the solutions will be adopted by a growing number of farmers.

e. Vision:

The outcomes of this project will contribute to internationally defined visions and policy goals, particularly in the areas of improved water quality and the transition toward circular agriculture. By demonstrating practical, scalable solutions, the results will enable substantial progress in reducing nutrient losses, enhancing soil health, and increasing resource efficiency. These developments will not only support environmental objectives but also strengthen the resilience and sustainability of the agricultural sector. In the long term, this is expected to drive a fundamental system change in agriculture, aligning with European and global ambitions for climate-smart and nature-inclusive farming.

NBS site – the United Kingdom

a. Reality

The UK has two experimental sites in the South-East of the UK that represent regions used mainly for arable crop production. The two sites have contrasting soil types; the surrounding farms are dominated by cereal production, but sugar beet is commonly grown on the lighter soils represented by the Brooms Barn experiment. Arable farms in the South-East of the UK are facing pressures from farm economics, agronomy and government policy. Firstly, commodity prices have not kept pace with rising input costs (including fertilisers and diesel), leading to reduced margins. In recent years, this shortfall has been compensated for agri-environment subsidy schemes, but the UK government has recently capped the amount that can be spent from the public purse to support farmers. Agronomically, farmers are facing pressure from pesticide-resistant weeds, diseases and pests (reducing yields and efficiency of inputs) and climate change (including extreme weather events). Finally, government policy to achieve carbon neutrality by 2050 has focused attention on the contribution of agriculture to greenhouse gas emissions; after livestock, the manufacture and use of inorganic fertilisers is the biggest factor.

Although technological solutions exist for addressing these challenges (including the use of precision application of pesticides and fertilisers), increasingly farmers are looking to nature-based or 'regenerative' approaches to reduce inputs and improve the resilience of their farm businesses. This is evidenced by the popularity of the regenerative farming festival, Groundswell and the emergence of farmer co-operatives marketing premium brands based on regenerative principles, for example, Wild Farmed wheat.

b. Inputs

The Large-Scale Rotation Experiments at Harpenden and Brooms Barn take a multi-input / multi-output approach. We are exploring the *combination* of the following nature-based or 'regenerative' solutions:

- Crop diversification
- Reduced tillage
- Organic inputs and cover crops

…on the multiple properties of the system that address the environmental, agronomic and economic challenges described above:

- Input use efficiency of fertilisers and pesticides (reducing costs and losses to the environment)
- Pest, weed and disease pressure (reducing spend and negative impact of pesticides)
- Soil condition, including organic carbon (mitigating climate change and increasing resilience to climate change)

c. Outputs

Our approach allows the *contextualization* of potential benefits of a single nature-based solution for multiple outcomes. For example, the benefit of applying compost in arable rotations for yield, fertiliser use efficiency, and soil carbon will depend on the crop it is applied to, the local soil type and the tillage regime. These factors will also affect the potential negative effects on pest (slugs) and disease pressure. We are providing data to explore these alternative scenarios to inform decision-making and facilitate discussion.

Outputs from the LSRE are currently mainly focused on academic analyses and papers, but as part of Trans4num, the results are being interpreted for different groups of stakeholders, and alternative extension material is being prepared.

d. Outcomes

As opposed to providing direct advice or decision support to the farmer and farm advisory communities, the output from the LSRE will be used to *inform* decision-making in a more adaptive, less directed way. Every farm will be a unique combination of environmental, farm system and socio-economic conditions. Understanding this context in terms of the initial conditions, potential options for improvement and drivers of change is foundational to our approach – we contend it is not possible to identify a universal optimal system or solution.

For example, a farm may have a simple rotation in a ploughed system on heavy land.
The data from the LSRE could be used to explore the relative, additional benefits of: 1) introducing spring barley into the rotation, 2) adding compost to the spring barley, and 3) also reducing tillage to economic, environmental and agronomic outcomes. The conversation would be very different for a farm on light land that already has a diverse rotation, but because of our approach to the design of the LSRE, the same data could be used.

e. Vision

There are strong imperatives and an acceptance in the farming community that alternative ways of farming are needed that improve economic, agronomic and environmental sustainability. However, there is a lack of evidence base for 'what works where' and suspicion around some of the claims made for nature-based solutions. As some interventions also take time to deliver tangible benefits (and may even have a net cost in the short term), evidence on the time scale for improvement is also required. Our vision, using data from the LSRE combined with output from similar platforms, is to provide a robust, accessible evidence centre for framers and advisors to support this transition to more sustainable systems.

Key insights gained

1) Farmers and advisors may not have a specific interest in an individual nature-based solution or in the LSRE as a platform *per se.* But they have many pressures and issues that the results of the LSRE are relevant to. Starting with those issues (e.g., soil carbon or herbicide-resistant weeds) and feeding in potential nature-based solutions is proving more effective.

2) The LSRE has been designed with academic outputs primarily in mind; statistical design has, therefore, taken precedence over practical demonstration. We need to think more carefully about how we anticipate stakeholder engagement in the layout of field experiments and how the data are interpreted in a way that is relevant and accessible.

Next Steps (summer and autumn 2025)

We are working with the group at FiBL to adapt the DST nutrient management tool to the cropping system represented by the LSRE. This will involve obtaining statistics on cropping patterns in the surrounding region and estimating the benefits of the nature-based solutions at different scales.

Appendix 2 -Notes from workshop at GA

NBS-site presentation sketching the transformation pathway

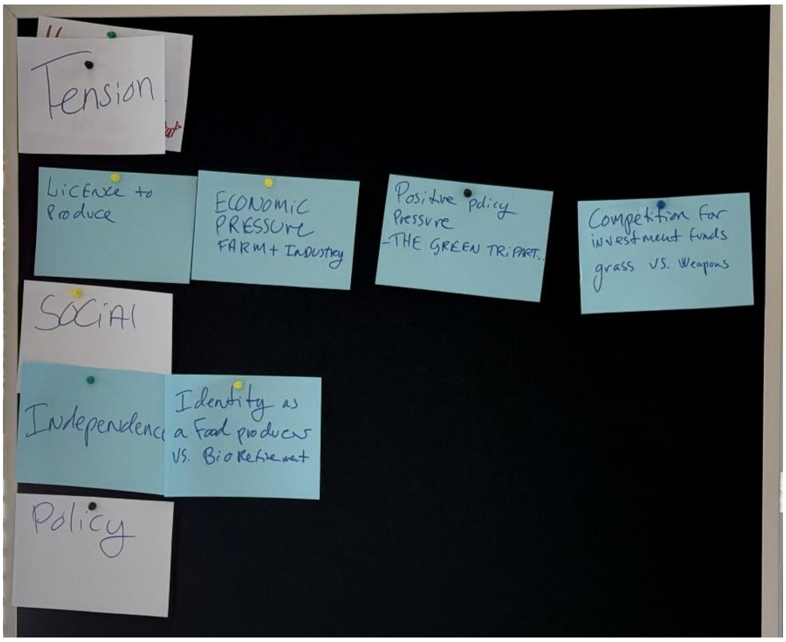
Denmark

- The tensions ranking was found not to be useful. They would rather think all tensions should be mentioned:
    - Economic: supply and demand are important drivers of change
    - Social:
        - farmers and the industry are READY
        - perceived ways of doing farming or in the industry, if you do not adhere to doing lower intensity, then the change cannot come about.
        - Independence plays a big role in keeping the status quo.
        - Cultural elements of understanding what is "sustainable", what is the more "natural solution"
    - Policy: Green Tripartite of 2024 and CAP 13
- They used an example from ICOEL: they are the main character promoting the research topic and finding solutions on nitrate leaching and promoting cover crops/grass clover
    - Additionally, they work on the DST on the landscape level-> There were discussions on its usability and different scales DST can support
- There were various views from all DK partners with different characters: Should the storytelling be done for all the characters? Should there be one overall or multiple little stories?
    - The main character could be the nutrient leaching at the Limfjord catchment, but the storyline would need to be expanded. Integrate the various perspectives into the storyline
    - The biorefinery has already a long past story -> with more political pressure, there came new regulations (climax in story arc)
    - Lots of policy push currently

Reactions:

- Mark: Are we aiming to do videos about innovations or how they feed into transformation? We are currently just listening to the stories; at the moment, we have a blank piece of paper.
- Organisational innovation is the focus in Denmark. Mark: could also be a video

Feedback: consider the audience for the story. Testing if the audience is understanding and responding to the story.



Netherlands

- There are two settings: the wheat farmers' area and the seed potato area
- Tensions: economic (high land prices and low margins leading to more cash crops but also triggering innovation), Social: farm succession, political (CAP tensions + funding), environmental (pressure for farmers through chemical input dependence) -> decrease the use!
- Focus was here on the seed potato area
- Planty organic (looking at the whole farm system) is a vision towards circularity, vs. at the moment still depending on lots of inputs -> it is an example farming system (hopefully lasting) long term. Current practices are characterised by lots of inputs. The logic would be to decrease the inputs, but it isn't easy to implement. SPNA implements alternative systems/farms of 15 – 20 ha, to construct 'future farms' in exchange and close collaboration with farmers, aiming at 50% of input and 90% of outputs
- Trying out creates new questions that are integrated into new research
- The planty organic trial was initiated by farmers who were dealing with pressures; new actors involved now are also breeders, advisors (mainly private sector), and researchers. Advisors are an important part of the system as well as the researchers; within 3 or 4 years, we will be ready to show farmers what they could implement on their own farm

Reactions:

- What results can be shared within the time frame of the trans4num project? What story could be interesting for farmers from DK? Results about the cover crops; the project is built for the farmers in the region, so most likely Danish seed potato producers could be interested.

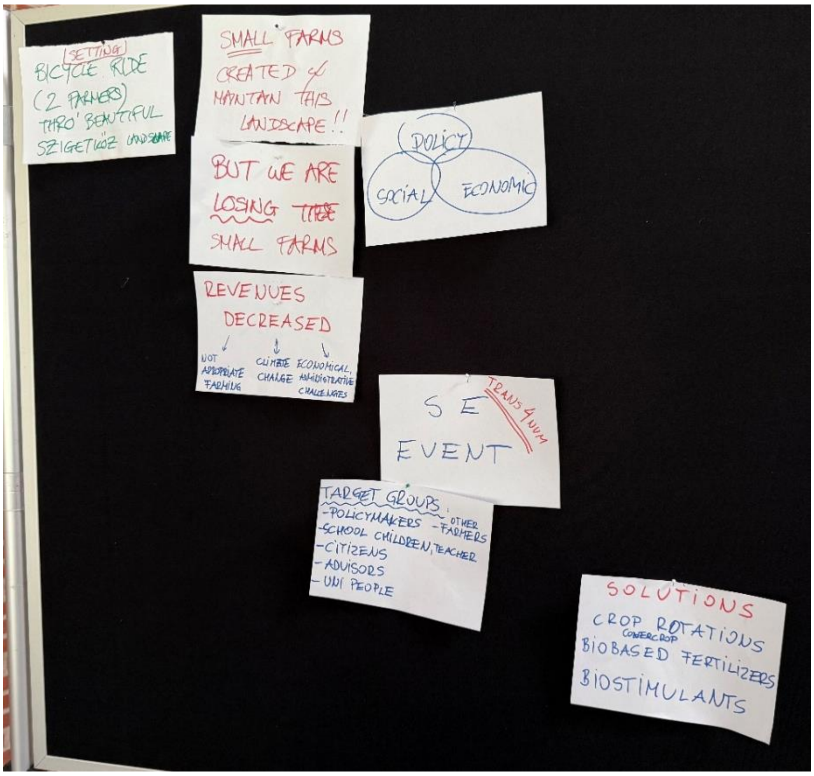
- What is the main message? Make your growing system less vulnerable to circumstances, more resilient
- Is there a danger if you only talk about cover crops to single out innovations from the bigger system picture? Can you talk about a single innovation? Yes, a cover crop innovation could be an enormous change with a massive impact (both positive and negative)
- Mark: There is a spectrum between sites advising and receiving advice, e.g., embeddedness through the educational NGO in Hungary. The aspect of working with suppliers and advisors can be enriching to the story (nt): Involved advisors for impact because they are in continuous contact with farmers (irrespective of whether or not private company-related ones)

Hungary

- Szigetköz area (setting): (windy), maize (no rain), good sorghum (coping well with conditions), heavy rain (soil washed out), leaching, no earthworms
- Stakeholder engagement: international groups -> politicians, farmers, school children, citizens, advisors, key persons, knowledge
- HU team takes up questions of Stakeholders during the events
- Goal: Providing solutions against environmental pressure, starting with challenges and trying to provide solutions
- Finances are a challenge
- Final event hackathon with students/participants of the precision agricultural master course

Reactions:

- Stakeholder group is wide: it was opened up from 3 villages to 10 villages with more advisors, but also events within the University with a wide range of people, such as from Slovenia, cooperation with a crop company that used the example with farm managers from bigger farms from HU and the Slovak Republic; one event with advisors.
- Added value of trans4num, put results into daily business and built on it
- Morten: How does transformation happen (diffusion into society)? This happens through Zoltan as he is active in pedagogy and tourism with educational innovation tools to spread news. Zoltan refers to the demonstration objects they have implemented and already shown to around 1000 visitors. They show only good examples of crop rotations and soil profiles. The key is an easy and good explanation.

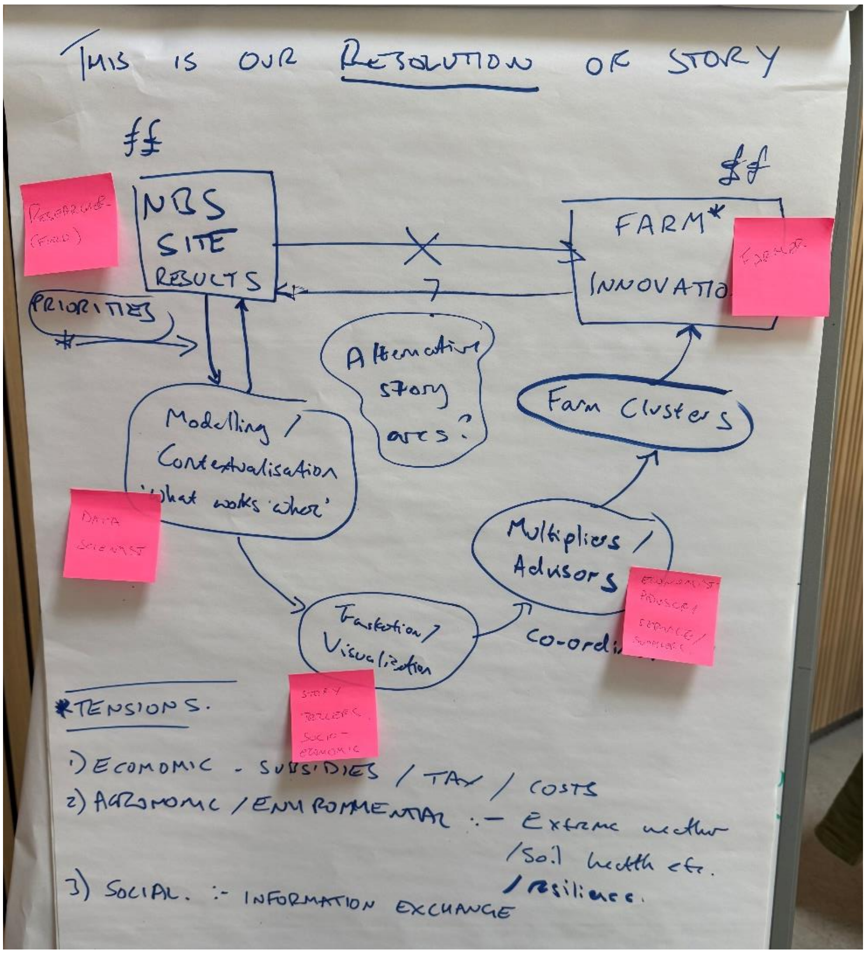


- Anke: Do you plan an impact assessment? -> They are using the survey from the UK

Feedback: The way the story was made interactive (they made a little role-playing of describing the problems and having a national stakeholder meeting) was a very appealing way of understanding the story. However, there should be more links to the scientific reports. Small but rich insight into the reality of the national situation.

UK

- There is a big difference between the UK NBS sites and other trans4num sites in that there was not a particular aim or challenge, but it is a platform to have long-term relevance (long-term experiment)-> they created alternative story arcs
- Knowledge from the NBS site directly to farmers is mostly not happening. Therefore, there are actors in between needed
- Tensions: see photo



- Modelling can be fed by integrating farmers' questions, but it needs further steps to communicate results back to farmers, such as through visualisation.

Reactions:

- Is there a participatory platform in the UK? There are movements to bring farmers into action, and they also capture farmers' experiences
- Does RRES do policy recommendations? How does it take place? Yes, on an individual expert basis.
- Does RRES have a platform to engage with farmers and practitioners? Yes, there are such platforms, but they are not upheld by RRES. Capturing farmers' experiments would be a massive opportunity. One of the last events revealed: When communicating results to farmers, they gave the feedback that they don't always need certainty on results from research, but a tendency/ less certainty would be enough to work with-> Adrian: other experience - Farmers want clear data (if I put this much fertiliser - How much more will I gain)
- What is the story of RRES: The meta story is on RRES communication, where to put RRES as an actor into the centre, but there are several concrete NBS cases on weed management, compost manure and on the abattoir case that will be used as concrete innovation cases. There is a huge amount of data, and trans4num will not produce data for data's sake

Feedback:

- This was a very honest presentation of what the experiments are and what they are not. The site is a long-term experiment that is not designed for trans4num; however, RRES can extract effects of different types of perennial crops, compost, tillage, etc. These combinations are the NBS effects they investigate. So they use "already existing" data to say something about NBS.