Valorization Legumes Related Ecosystem Services

D6.3: Practice abstracts (Batch 1)

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[1] *Please consult the Grant Agreement: R: Document, report; DEM: Demonstrator, pilot, prototype, plan designs; DEC: Websites, patents filing, press & media actions, videos, etc.; DATA: Data sets, microdata, etc; DMP: Data management plan; ETHICS: Deliverables related to ethics issues; SECURITY: Deliverables related to security issues; OTHER: Software, technical diagram, algorithms, models, etc.*

[2] *Please consult the Grant Agreement: PU – Public, fully open, e.g. web (Deliverables flagged as public will be automatically published in CORDIS project's page); SEN – Sensitive, limited under the conditions of the Grant Agreement; Classified R-UE/EU-R – EU RESTRICTED under the Commission Decision No2015/444; Classified C-UE/EU-C - EU CONFIDENTIAL under the Commission Decision No2015/444; Classified S-UE/EU-S – EU SECRET under the Commission Decision No2015/444*

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VALERECO Consortium

No.	Participant organization name	Short name	Country
1	GEOPONIKO PANEPISTIMIO ATHINON	**AUA**	GR
2	ESC DIJON BOURGOGNE	**BSB**	FR
3	DELPHY BV	**DELPHY**	NL
4	UNIVERSIDADE DE COIMBRA	**UC**	PT
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9	INSTITUTO NAVARRO DE TECNOLOGIAS E INFRAESTRUCTURAS AGROALIMENTARIAS SA	**INTIA**	ES
10	AgriFood Lithuania DIH	**AFL**	LT
11	UNIVERSITA DEGLI STUDI DI FIRENZE	**UNIFI**	IT
12	UNIVERSITA DI PISA	**UNIPI**	IT
13	AG FUTURA TECHNOLOGII DOOEL SKOPJE	**AGFT**	MK
14	SCUOLA SUPERIORE DI STUDI UNIVERSITARI E DI PERFEZIONAMENTO S ANNA	**SSSA**	IT
15	HELVETAS Swiss Intercooperation	**HELVETAS**	CH

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Executive Summary

This document provides a collection of practical, easy-to-understand summaries and more detailed white papers on legume-based cropping system management practices tested during the first year of the VALERECO Living Labs. In addition to field-level practices, it also addresses systemic challenges that affect their adoption and outlines enabling conditions to overcome them. The materials are designed for farmers, advisors, and other agricultural stakeholders to encourage the adoption of legume-based farming practices.

The deliverable is structured into two main sections: the **practice abstracts** and the **white papers**. The practice abstracts are concise summaries covering a range of agronomic practices that integrate legumes to improve sustainability and profitability, together with an analysis of barriers to adoption and measures that can facilitate uptake. The topics include the use of legume cover crops to reduce fertiliser needs, crop rotations to improve subsequent yields, soybean production supported by winter pea cover crops, cereal–legume intercropping to improve soil health and land use efficiency, and strategies for overcoming systemic barriers to adoption.

To support the abstracts, five detailed white papers are included. These documents expand on the topics covered in the abstracts and present the evidence-based results from trials conducted at the VALERECO Living Labs by partner institutions AUA, IFVCNS, INTIA, UC, and UNIPI. They provide the scientific validation and in-depth analysis needed to translate the environmental benefits of legumes into quantifiable economic outcomes for farmers.

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List of abbreviations

BPS	Basic Payment Scheme	**LCA**	Life Cycle Assessment
CAP	Common Agricultural Policy	**LCCs**	Legume Cover Crops
CCs	Cover Crops	**LLs**	Living Labs
CO_2	Carbon Dioxide	**N**	Nitrogen
DLIH	Digital Legume Information Hub	**N_2P**	Nitrous Oxide
DSS	Decision Support System	**OM**	Organic Matter
ES	Ecosystem Services	**SMEs**	Small and Medium-sized Enterprises
EU	European Union	**WP**	Work Package

1 Introduction

1.1 Project Summary

VALERECO aims to promote the adoption and understanding of the value of legume crops towards transition to sustainable, productive, climate-neutral, environment-friendly, and resilient farming systems. Moreover, the project aims to quantify and enhance the environmental and economic value of Ecosystem Services (ES) provided by **4 minor or underutilised and 8 major legume crops**, seeking to encourage diversification of farming practices throughout the European Union and Associated Countries. The aforementioned are willing to contribute to healthier and sustainable diets and climate change resilience.

The **identification** will be achieved through (1) a thorough analysis of the ecosystem-services legacy and (2) the investigation of gateways for penetration of legumes and their associated ES to the new CAP.

The **valorization** will be implemented through the establishment of nine Living Labs (LLs) (Figure 1) to conduct: (1) behavioural design strategies to promote the adoption of legumes in production and consumption, (2) on-station participatory trials to assess the performance of major and minor-underutilised legume crops in diversified farming systems, (3) to demonstrate and co-create technical economically and environmentally assessed solutions for legumes inclusion in cropping systems.

Figure 1. Living Labs of VALERECO.

The **quantification** of the provided Ecosystem Services will be occurred through the development of indicators, which will be based on the results of the on-station trials and the demonstration events of the Living Labs. These indicators will further support the creation of the Decision Support System models. The quantification of ecosystem services through the indicators will also be assessed through a cost-benefit analysis and a Life Cycle Assessment (LCA).

The **dissemination** will be realised through (1) the development of a Digital Legume Information Hub (DLIH) to upscale and maximise the uptake of VALERECO's results, (2) the development of a Decision Support System (DSS) to support the decision-making of farmers and advisors for legumes adoption, and (3) the generation of capacity building material made available to the public through an E-learning Platform.

1.2 VALERECO Consortium

The consortium consists of 14 partners and 1 associated partner, from 8 member states and 3 associated countries. The consortium is spread mainly over two geographical regions to ensure interactivity, communication, and feasibility of the proposed frameworks to address common challenges in different crops and farming systems under different European pedo-climatic conditions: Central/Northern Europe (Netherlands, Lithuania, Germany, France, Serbia) and Southern Europe (Portugal, Spain, Italy, Greece, North Macedonia) (Figure 3).

More specifically, to materialise its concept, VALERECO will bring together organisations coming from:

→ 7 universities (AUA, UC, UNIFI, UNIPI, SSSA, WR, LUH) with significant research capacity in legumes, weed science, agriculture, digital agenda, impact assessment and policy design

→ 3 research institutes (BSB, IFVCNS, INTIA) with significant research capacity in legumes, weed science, precision agriculture, organic production, behavioural research, social sciences and humanities, economics and marketing and policy design

→ 1 advisory organisation (DELPHY) with experience in agri-food related sectors providing services, consulting, transfer of knowledge, technologies, and innovation

→ 1 non-profit organisation (RFF) to engage end-users in co-creation, behavioural research and build capacity

→ 2 farmers' organisations (AFL, AGFT) with wide end-user networks (farmers, SMEs, consumers) related to agri-food and digital agriculture

→ 1 independent development organization (HELVETAS) to build capacity in Ukraine, Moldova, and Serbia

The selection of the partners was strictly based on criteria of experience, expertise and complementarities, and specific roles and responsibilities were appointed according to the partners' capability and capacity. Their complementary profiles guarantee the achievement of the ambitious project objectives, while their experience from past and ongoing projects proves their capacity and ability to access and exploit all the necessary infrastructure for the implementation of the project. Expertise in legumes, ecosystem services, agricultural sciences, as well as smart farming, ecology, biology, social sciences, LCA and marketing are covered by corresponding partners, following the interdisciplinary approach. It should be mentioned that VALERECO relationships among some of the partners of this consortium already exist because of past and ongoing successful collaborations, which is expected to be valuable for a quick "jump start" of the project. Additionally, consortium partners ensure their internal gender equality issue in all aspects of research and innovation, which is scaled up in the consortium. All the partners have previous proven experience from their participation in numerous EU and National funded projects.

Figure 2. Map with the partners spanning through the two climatic regions of Europe.

2 Practices Abstracts

This first batch of practice abstracts delivers an easily understandable way for farmers, advisors, and other stakeholders to utilise the outcomes of VALERECO Living Labs. They cover practical agricultural techniques that incorporate legumes to make farming more sustainable and profitable. These abstracts help farmers valorize ecosystem services by translating the environmental benefits of legumes into tangible economic outcomes. By outlining direct advantages, such as lower input costs and improved soil health, the abstracts provide a clear pathway for farmers to increase their farm's profitability and resilience.

Practice abstracts are available at EU-CAP Network VALERECO page and can be accessed through here.

2.1 Cover crops and their benefits to specific following crops

Reducing high fertilizer costs, improving soil health, and increasing farm resilience are common goals for agricultural practitioners. Legume cover crops (LCCs) offer a practical and sustainable solution to enhance cropping systems. This practice provides an opportunity to naturally fertilize the soil and suppress weeds, directly increasing the productivity and profitability of primary cash crops.

These plants naturally capture nitrogen from the atmosphere, supplying the soil with **40–80 kg of free nitrogen per hectare** and drastically cutting fertilizer needs.

Integrating LCCs like vetch, clover, or peas into crop rotations provides significant benefits. This practice improves soil structure and water retention, leading to **cash crop yield increases of around 4–8%**. For instance, studies show soybean yields can increase by nearly 5% after five years of cover crop use, and by over 11% in drought years. While proper management is key—as outcomes can vary between crops like wheat (positive) and sunflower (risk of water competition)—the long-term improvement in soil health and farm productivity is consistently positive.

LCCs can be implemented on-farm with straightforward management. The primary costs are for seeds and planting, but the return on investment is substantial.

- Implementation leads to lower fertilizer and herbicide bills, higher and more stable yields, and healthier soil that holds more water during dry spells.
- **To legume cover crops**:
    - **Select the Right Mix**: Choose LCCs (or a mix of legumes and grasses) suited to the specific region and main crop schedule.
    - **Time Termination**: The cover crop should be terminated 2–3 weeks before planting the cash crop to allow the green manure to break down.
    - **Adjust Inputs**: After termination, soil testing is recommended to adjust and reduce fertilizer applications, thereby capitalizing on the natural nitrogen boost.

2.2 Overcoming Barriers to Valorizing Legume Ecosystem Services

VALERECO explores several operational, agronomic, social, economic, institutional and cultural barriers that prevent farmers from taking full advantage of legumes. While crops like beans, peas, and lentils can reduce fertilizer costs and build healthier soil, many growers are held back by challenges such as unstable yields, high start-up costs, a lack of practical knowledge, and poor access to markets. The goal is to make growing legumes a bit more sustainable and an attractive choice for integration in diversified farming systems.

Results

VALERECO is working on a strategic roadmap for making the use of legumes more attractive for production and consumption. Key solutions involve among others:

- promoting new breeding programs for resilient and better performing legume varieties,
- better fitted legume varieties suited to diverse farming systems and adapted to ongoing climate change repercussions,
- advocating for new policies that financially reward farmers for the environmental benefits they provide, such as improved soil health and carbon storage
- incentivizing the wide use of legumes in healthy diets by involving consumers and other actors across the agrifood value chains into co-created transformation pathways

Practical recommendations for end-users

Integrating legumes into rotations can significantly decrease reliance on expensive nitrogen fertilizers and the implementation of unsustainable and harmful agricultural practices. Over time, legume-based diversification leads to healthier, more drought-resistant farms and more stable, long-term productivity for the entire agricultural holding. The primary benefits for producers constitute lower input costs and a surge of ecosystem services such as pollination, water retention, and soil health, especially when combined with conservation tillage and other nature positive agricultural practices. While there may be initial investments in new seeds and training, adoption can begin on a small scale.

2.3 The role of legumes in sustainable crop rotation

Continuously sowing cereal crops like wheat on the same land presents significant challenges for farmers. This practice, known as monoculture, leads to higher costs due to an increased need for nitrogen fertilisers and plant protection products. It also creates long-term problems with recurring weeds, pests, and diseases that become harder and more expensive to manage over time. This project addresses the opportunity to break this costly cycle by introducing a simple, sustainable, and profitable alternative.

An important solution is to integrate leguminous crops, such as peas, into the rotation. Long-term experiments have proven that this strategy delivers multiple benefits. By alternating between cereals and legumes, farmers can naturally disrupt the life cycles of persistent weeds, pests, and diseases that thrive in monoculture systems. Most importantly, legumes have the unique ability to fix atmospheric nitrogen in the soil, providing a natural source of fertiliser for the next crop and significantly reducing the need for synthetic fertilisers.

Farmers can directly apply these findings to improve their bottom line and farm health.

- Sowing a legume crop like peas before wheat can boost the subsequent wheat yield by as much as **17%**.
- This rotation with legumes can lead to direct cost savings, reducing the need for nitrogen fertiliser by an average of **40 kg per hectare** in the following crop.

- Crop rotation also serves as an effective tool for integrated pest and weed management, decreasing reliance on chemical sprays and lowering the risk of herbicide resistance.

The primary step is to diversify the crop plan to include a legume in a rotation. This makes the entire farming operation more resilient and sustainable. By reducing input costs while increasing yields, rotating with legumes is a powerful strategy to enhance farm profitability.

2.4 Soybean production in the system of winter cover crops

VALERECO aims to find a practical way for farmers to **improve soybean yields** in challenging, semi-arid conditions. The goal is to increase productivity and meet the growing demand for plant protein, all while making farming more sustainable and **reducing the need for chemical fertilisers**.

The IFVCNS team tested an effective solution: planting **winter peas as a cover crop** before the main soybean crop.

This method was proven to **significantly boost soybean yields**. It works by enriching the soil with beneficial microbes and naturally adding nitrogen, a key nutrient for soybeans. The study confirmed that this is a practical and beneficial system for soybean production.

Practical Advice for Farmers

This strategy offers direct benefits on the farm. By planting **winter peas**, growers can expect the following benefits:

- **Higher Yields:** The most important result is a bigger, better soybean harvest.
- **Lower Costs:** The peas naturally "fix" nitrogen from the air into the soil, cutting down on the need to buy expensive nitrogen fertilisers.
- **Healthier Soil:** This practice improves the soil's structure, reduces compaction from machinery, and helps suppress weeds naturally.

Keep in Mind:

- There is an **initial investment in the cover crop seed and the labour** for planting and later terminating it.
- To get the best results, the **cover crop must be terminated at the right time** so it doesn't compete with the soybeans for water or nutrients.

The choice of cover crop and management plan should be **tailored to the farm's specific soil type and climate**.

2.5 Intercropping with legumes to improve productivity and soil health

VALERECO aims to address a wide range of modern agriculture challenges through the introduction of legumes in diversified cropping systems with emphasis on sustainable and effective intercropping schemes. The proposed intercrops aim to increase crop yields and farm profitability while reducing inputs, costs and environmental risks.

Specifically, legumes, as for example peas, clovers, lentils, chickpeas etc., are combined with cereal cultivation to create functional intercrops and achieve optimal land use efficiency. Soil nitrogen enrichment through legume nitrogen fixation is a prominent benefit of such legume-cereal intercrops. In addition, the simultaneous presence of crops with different functional characteristics in the same field for a while, leads to optimal resource exploitation, due to the complementarity of resource use by the intercropped plants.

There are four types of intercropping: mixed-intercropping (both crops in the same row), strip-intercropping (alternate crops strips), row-intercropping (alternate crop rows), and relay intercropping (crops co-exist for a while). Implementing this strategy can offer:

- **Environmental Benefits:** Over time, the soil will become healthier with better structure, improved water retention, and natural weed suppression, securing the future productivity of your land. For livestock operations, intercropped forage also offers higher protein content. Legumes contribute to more resilient agroecosystems that are better able to withstand climate variability and disturbances.
- **Economic Benefits:** The most immediate benefit is a significant reduction in fertilizer and chemical pest and weed control inputs.

To summarize, although important challenges should be addressed to their wide adoption in the new era of agriculture, legume-based intercropping systems offer a sustainable and effective approach to improving low-input agroecosystems and promote higher productivity and profitability compared to monocultures.

3 White Papers

The five white papers provide a comprehensive look into the initial research and trials conducted at the VALERECO Living Labs, reinforcing the summaries found in the practice abstracts. Each document, prepared by partner institutions like AUA, IFVCNS, INTIA, UC, and UNIPI, delves into a specific aspect of integrating legumes into farming systems. The topics are diverse, most of them focus on practices tested in the field, such as intercropping legumes with cereals to improve land use efficiency, using winter peas as a cover crop to boost soybean yields, and implementing crop rotations to break the costly cycle of cereal monoculture.

Furthermore, the collection examines the broader context, addressing the various operational, economic, and institutional barriers that hinder the widespread adoption of legumes and offering strategic solutions to promote their use.

These white papers play a critical role in communicating the value of ecosystem services provided by legumes. They combine field evidence, practice-oriented insights, and barrier analysis to demonstrate the economic and environmental benefits highlighted in the project.

This knowledge base is crucial for convincing farmers, advisors, and policymakers to adopt these sustainable practices. By providing in-depth analysis, the white papers serve as a key resource for stakeholders, building credibility and empowering them to make informed decisions that support resilient and profitable agriculture.

Intercropping with legumes to improve productivity and soil health

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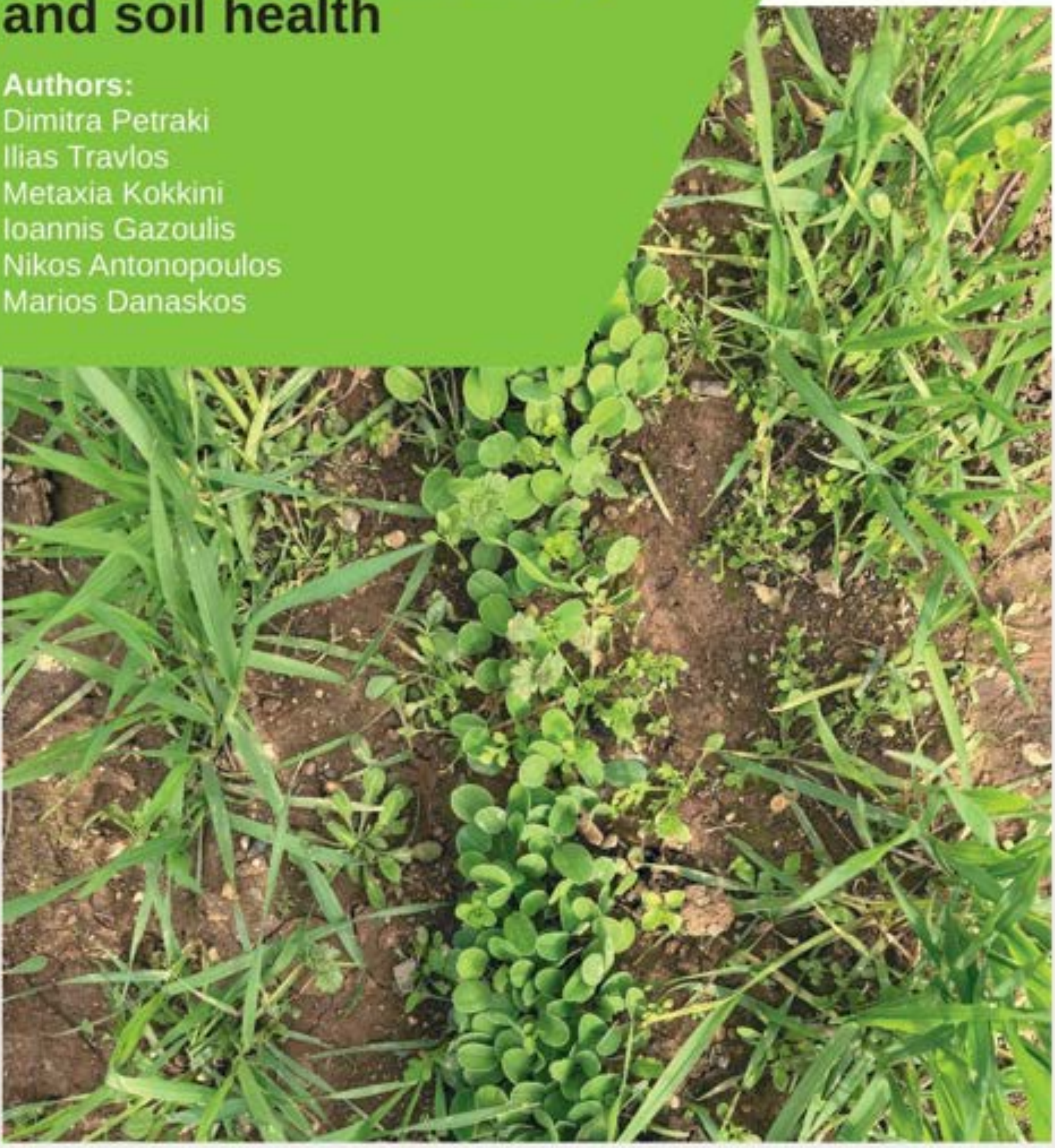

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Introduction

Intercropping is a cultural practice, where two or more crop species are grown simultaneously in the same field during overlapping growing seasons. There are four main types of intercropping: row-intercropping where crops are grown in distinct rows, mixed- intercropping involving crops grown without distinct row arrangement, strip-intercropping featuring crops cultivated in multiple-row strips and relay intercropping entailing sequential planting of crops with overlapping growth phases. The system generally integrates a main crop, usually cereal or cash crop, with a secondary crop, often a legume, that provides complementary ecosystem services. In cereal–legume intercropping, important cereals are often paired with grain legumes. For example, maize is commonly grown alongside soybean and wheat with field pea. In addition to cereal–legume combinations, intercropping can also involve two legume species, either annual or a mix of annual and perennial types. Such mutual legume intercropping enhances forage yield, improves nitrogen use efficiency, and contributes to weed suppression and system resilience. For instance, pairing red clover with pea or combining faba bean with grass pea has shown promising results.

Enhancing agricultural productivity through legume-based intercropping

In these systems, legumes represent a key functional group due to their unique biological properties and agroecological benefits.

Legumes convert atmospheric nitrogen into a plant-available form through a symbiotic relationship with rhizobia in their root nodules. The fixed N can benefit non-legumes in intercropping systems or serve as a nutrient source for subsequent crops in rotational systems. The resulting nitrogen enrichment benefits the associated non-legumes and improves soil N pools in the soil, leading to high yields. Therefore, the presence of legumes can reduce fertilizer inputs and nutrient leaching into groundwater. Beyond nitrogen, legume-based intercropping systems further optimize resource use compared to monocultures and increase the resilience of the cropping system.

Legume-based intercropping to enhance soil health and biodiversity

Furthermore, intercropping with legumes provides many additional benefits to soil health and quality by reducing soil erosion, improving soil processes, increasing moisture retention, maintaining soil fertility, increasing nutrient cycling, enhancing soil conservation, and suppressing weed infestation.

These advantages are further enhanced when legumes are intercropped with cereals, as their complementary root-zone interactions improve soil structure, the deeper root systems of legumes break up compacted layers, improve soil aeration, and promote stronger soil aggregates. Conversion from traditional monocultures to diversified cropping systems can further enhance carbon sequestration by maximizing biomass production and soil organic matter accumulation. Moreover, legumes can enhance microbial abundance and activity, which also contributes to improved soil health. In addition to soil health, incorporating legumes in intercropping systems increases the efficiency and resilience of agricultural systems while promoting soil and plant biodiversity. Many species from the Fabaceae family rely on animal-mediated pollination, providing floral resources such as nectar and pollen that attract a wide range of insect pollinators, and thus improve the overall productivity of the intercropping system.

The role of legumes for climate change mitigation

Beyond the ecological and agronomic benefits, intercropping systems with legumes also play a vital role in climate change adaptation. By reducing reliance on synthetic nitrogen fertilizers, legumes have the great potential to reduce greenhouse gas emissions such as carbon dioxide (CO_2) and nitrous oxide (N_2O) compared to conventional agriculture with mineral N fertilization. At the same time, the increased carbon sequestration in the soil plays a crucial role in efforts to mitigate climate change. By diversifying cropping systems and enhancing soil microbial biomass, legumes contribute to more resilient agroecosystems that are better able to withstand climate variability and disturbances. Notably, certain legume species, especially when associated with rhizobia, help to break down pollutants and remediate contaminated soils, thus indirectly contributing to climate-friendly land management.

Figure 1.

Ecosystem services provided by legumes in an intercropping system, highlighting contributions to productivity enhancement and soil health improvement.

Conclusion

Legume-based intercropping systems offer a sustainable and effective approach to improving low-input agroecosystems. By naturally incorporating nitrogen through biological fixation, these systems reduce reliance on synthetic nitrogen fertilizers, minimizing the environmental damage associated with nitrate leaching and nitrous oxide emissions. Intercropping legumes and cereals is rooted in the principles of environmentally friendly agriculture and improves not only soil health and biodiversity, but also the nutritional quality and yield of forage crops, particularly through higher protein content. This practice also promotes higher productivity and profitability per unit area compared to monocultures. By improving the nitrogen cycle, reducing fertilizer and pesticide use and increasing crop resilience, legume intercropping is proving to be a powerful strategy for improving agronomic performance and environmental sustainability.

Figure 2.
Row-intercropping of sulla (*Hedysarum coronarium*) and wheat (*Triticum durum*).

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Soybean production in the system of winter cover crops

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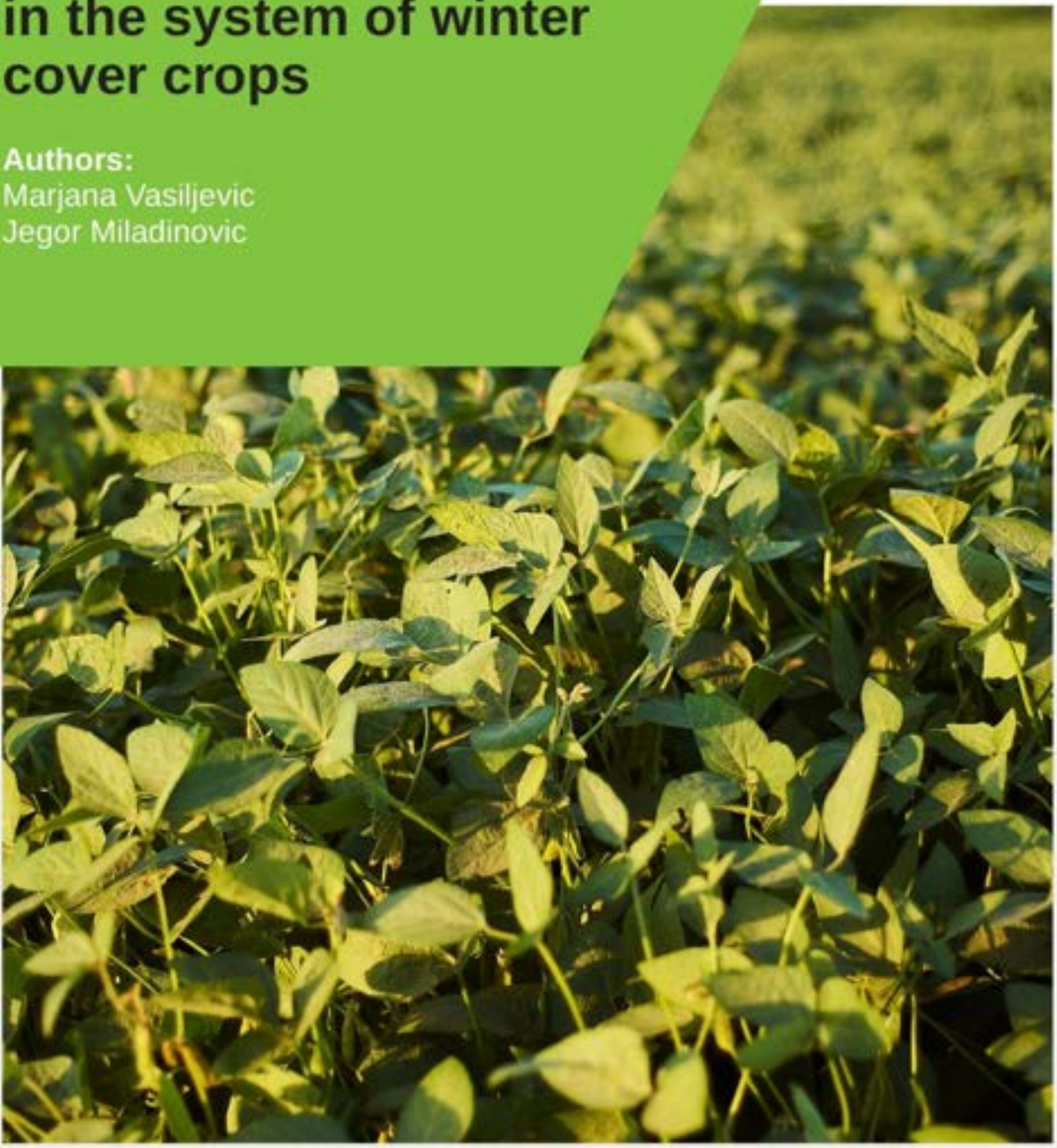

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The agroecological practices that will be tested and demonstrated based on different combinations of the 3D of diversity: (a) genetic (legume genotypes), (b) species (intercropping, legume mixtures, crop rotations), and (c) spatial diversity (strip intercropping, agroforestry, buffer strips, EFAs). Each LL will implement 2 to 3 agroecological approaches for 3D diversification and incorporate agroecological practices for the reduction of pesticides and N fertilizers needs (e.g., mulching, green manure etc.).

Considering the changed conditions of production in terms of climate, changes in assortment and increasing demand for protein sources of plant origin, as well as the great importance of soybeans in animal and human nutrition, there is a constant need to improve the technology of growing this plant species in semiarid conditions. One of the ways to improve technology is the adaptation of existing cultivation measures that can positively affect the productivity of this plant species Numerous on-farm advantages might result from the integration of winter cover crops in soybean production, which can also have major ecological effects on the farming system. Cover crops are crucial for enhancing the physical, chemical, and biological characteristics of soils in sustainable production.

In VALERECO, for trial in Serbia, winter pea is the selected winter cover crop, advantages following the implementation of winter cover crops include:

1. Enhancement of soil quality through better physical and chemical properties.
2. By including a legume, N fixation is guaranteed, boosting the subsequent crop's yield and quality.
3. Release nitrogen to the next cash crop.
4. Reduced compaction of the soil.
5. Control of weeds.
6. Enhanced biodiversity.

In addition, following points need to be considered:

1. Competition with the primary crop for nutrients and moisture (e.g. moisture usage).
2. The price of planting, establishing, and termination cover crops (mechanically).
3. Cover crop termination time/practice.

When planning the integration of cover crops, it is essential to consider the agro-ecological conditions, including location and soil type.

The farm orientation—whether it is focused on plant or livestock production—also influences cover crop selection and management. Additionally, the timing of cover crop planting and termination, along with the systems or approaches applied, plays a critical role in ensuring effectiveness and compatibility within the cropping system.

Many studies have observed how the introduction of legumes, e.g., soybeans, influences changes at the crop rotation level. In this study, the perspective was different: how can winter CCs influence soybean production as a cash crop under sustainable production schemes? The hypothesis that winter CCs would improve soybean yield was supported by a significant increase in the soybean yields between the tested P + O as a CC and the control, and the types of production system (LIP or OP) were observed. In our study, there were no barriers to legumes (peas) being grown as a CC for soybeans. The results showed increased abundance and activity of microorganisms in the soybean rhizosphere, which primarily depended on production system and selected CCs. The findings of this study can be a keystone for production improvement in the sustainability dimension in regions throughout Southeast Europe, where a decline in crop rotational diversity has been seen, especially in soybean production.

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The role of legumes in sustainable crop rotation

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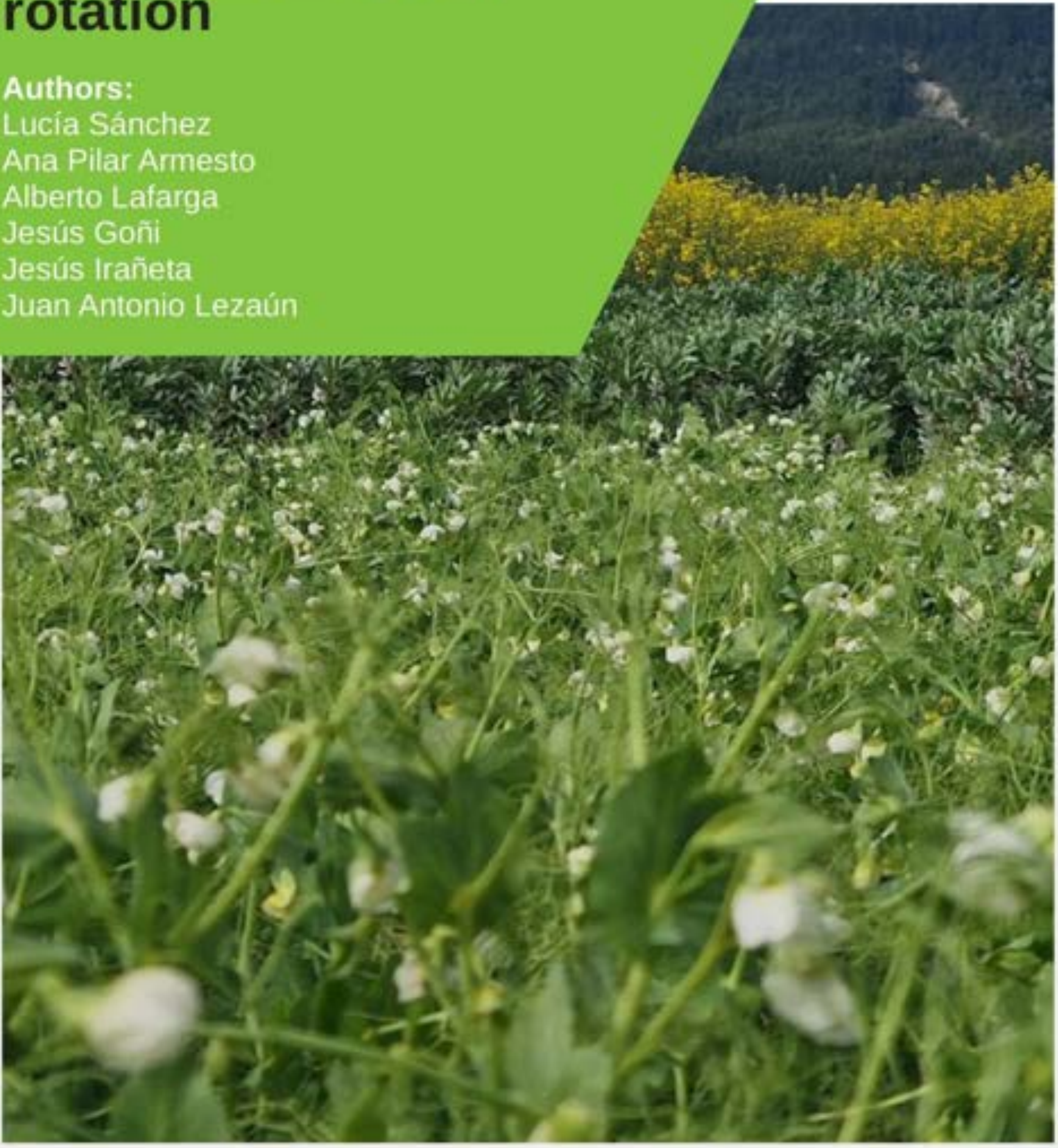

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Monoculture presents long-term problems, higher nitrogen consumption, greater risk of pests and diseases, especially weeds, and higher consumption of plant protection products.

The inclusion of legumes in rotations has a positive effect on the environment, which is further enhanced when the rotation consists of crops whose production requires high levels of inputs. With the introduction of protein crops economic profitability is maintained due to savings in inputs such as nitrogen fertilisers, both in legume cultivation and in subsequent crops, generally wheat, whose yield increases.

The advantages of alternative crops in terms of diversification of work dates, diversification of risks , and greater ability to combat weeds, pests, and diseases make them attractive when considering the farm

as a whole.

Legumes are suitable for all European regions, and there are many possible outlets for these crops, as their protein- and energy-rich grains can be used for the animal and human food market.

1.

Effect of legumes on production

Experiments conducted in long-term trials show benefits in different areas, such as increased production in successive crops (See Table 1).

The graph shows that the first wheat sown after alternative crops can provide a yield increase of more than 10% compared to yields on plots where a second wheat crop is repeated (dark green columns). If the previous crop is a legume, in this case peas, there is a 17% increase in wheat yield compared to the previous wheat crop. In addition, the second cereal sown after alternative crops can produce between 5% and 10% more than the resown cereal. (Light green columns). The second wheat crop sown after legumes, specifically peas, produced around 9% more than the resown wheat.

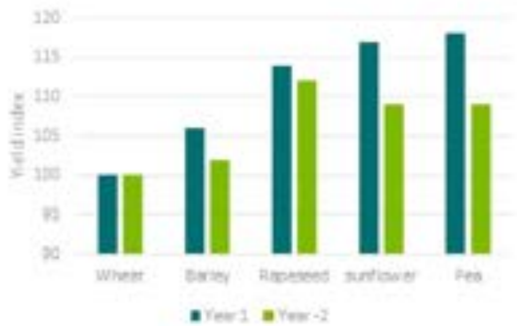

Table 1.

Yield index according to previous crop.

2. Interaction between nitrogen fertilisation and crop rotation

Legumes, due to their ability to fix atmospheric nitrogen through symbiosis with rhizobium bacteria present in the soil, do not require nitrogen inputs during cultivation and allow for a reduction in nitrogen fertiliser inputs in the following crop (Table 2).

The following table shows three response curves to different incremental nitrogen inputs. All lines show how wheat crop productivity responds to increasing doses of nitrogen applied to the trial, for each of the previous crops. The differences are noticeable. While previous crops such as legumes show more linear-plateau curves in which maximum yield is reached quickly, in the case of wheat, there is a continuous response of the crop to increasing doses, but sowing with a potential below that of other previous crops.

The introduction of peas into the rotation has enabled an average saving of 40 kg of nitrogen per hectare in the following wheat crop thanks to the nitrogen-fixing effect of the legume.

It has also increased the efficiency of this fertiliser's use by wheat, which required 26 kg/N per tonne of grain when sown after wheat and only 17.5 kg/N per tonne of grain when sown after peas.

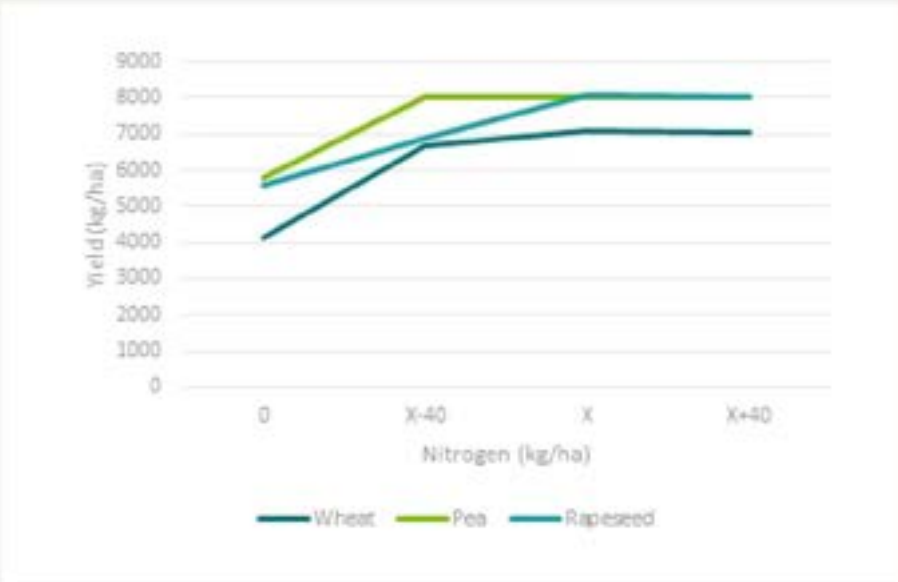

Table 2.

Wheat yield depending on the preceding crop and nitrogen input.

3.

Crop rotation and weeds

One of the best ways to combat weeds is to rotate crops on the same plot of land.

This allows us to: - Alternate species with different sowing times (autumn, winter, spring). - Alternate dense crops with crops in wide rows that allow for weeding between rows. Introducing legumes into crop rotation allows other active ingredients in plant protection products to be used, reducing the risk of resistance developing (Table 3).

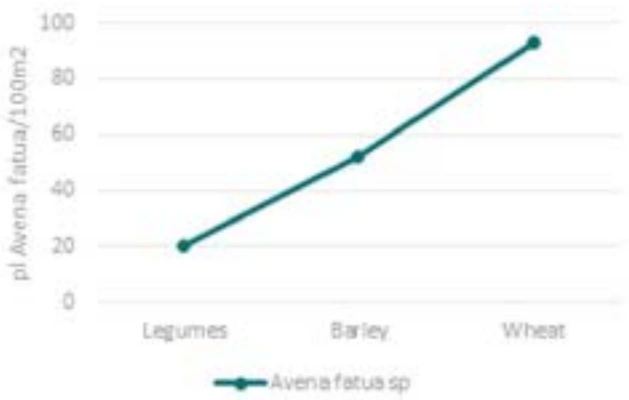

Table 3.
Avena fatua plants in cereal crops depending on the preceding crop

4.

Effect of crop rotation on pests and diseases

In addition to influencing factors such as production and fertilisation, including legumes in crop rotation helps to control pests and diseases in cereals by breaking their life cycle.

An example of this can be seen with the cereal pest *Zabrus tenebroides*, where it has been proven that its population decreases when other crops are included in the rotation, but the best precedent for its control is legumes (Table 4). Evaluations carried out on cereal crops show that legume preceding crops significantly reduce pest damage to crops.

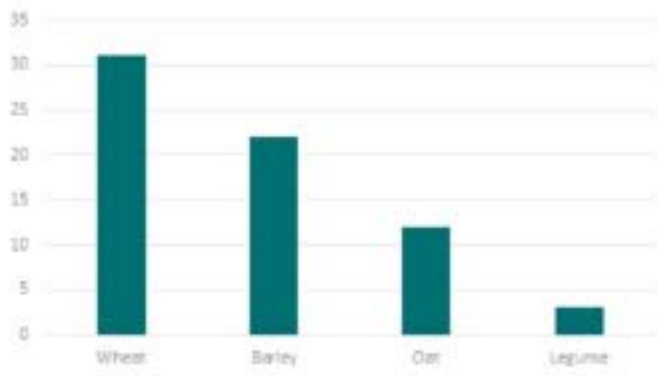

Table 4.
Plants/m^2 of wheat affected by *zabrus tenebroides* depending on the previous crop

Conclusion

The inclusion of leguminous crops in crop rotation provides agronomic and environmental benefits due to their ecosystem services. In addition to reducing inputs in their own cultivation and in subsequent crops, such as the use of nitrogen fertilisers, they contribute to more sustainable and resilient agricultural systems.

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Overcoming Barriers to Valorizing Legume Ecosystem Services

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Executive Summary

Legumes are central to agroecological transitions. Their ability to fix atmospheric nitrogen, enhance biodiversity, and improve soil health makes them vital for sustainable farming. Yet, despite well-documented benefits, legume-based cropping systems remain underused globally. This white paper explores the agronomic, economic, institutional, and cultural barriers limiting the recognition and widespread exploitation of ecosystem services provided by legumes and outlines strategic recommendations to unlock their full potential.

1. Introduction

Legumes such as beans, peas, and lentils offer multifunctional ecosystem services crucial for resilient agriculture. Beyond nitrogen fixation, these crops contribute to water regulation, conservation, and climate adaptation. However, uptake among farmers remains low. The reasons are multifaceted, ranging from scientific knowledge gaps to economic and cultural constraints. Bridging these divides requires an integrated strategy involving participatory research, policy reforms, and supply chain innovations.

2. Scientific Gaps and Agronomic Constraints

Knowledge fragmentation

Most existing research on legumes emphasizes short-term productivity outcomes, particularly nitrogen fixation and yield gains in cereal rotations. However, broader ecosystem services such as water conservation during droughts, pest and disease regulation, and long-term improvements in soil structure are understudied (Figure 1). Even when these benefits are acknowledged, variability in environmental conditions and farming practices make them difficult to quantify at the landscape scale.

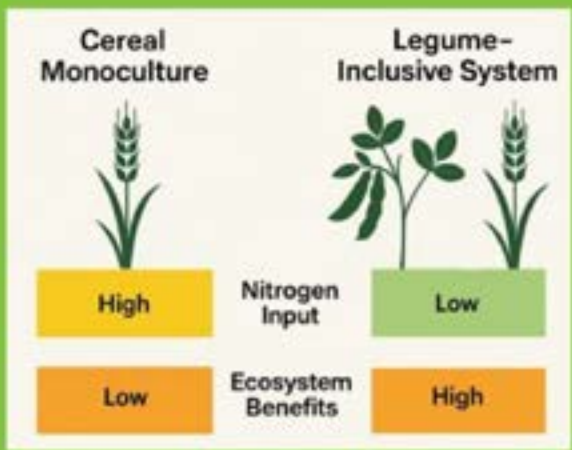

Figure 1.

Comparison of nitrogen input and ecosystem benefits between cereal monocultures and legume-inclusive systems. Legumes reduce nitrogen dependency while enhancing broader ecological functions.

Limited breeding and management tools

The lack of targeted breeding programs for legumes hinders their performance in diverse agroecosystems. Unlike cereals, many legume species are poorly adapted to modern agronomic demands. Challenges in synchronizing growth cycles in intercrops, managing nutrient competition, and handling pests and diseases are major concerns for farmers.

3. Economic and Market Disincentives

Financial barriers for farmers

Farmers frequently face higher upfront costs when adopting legume-based systems due to specialized seed needs, modified machinery, and training requirements. Legume yields are also less stable compared to conventional grains, making them less attractive to risk-averse growers. This is particularly problematic for smallholders who cannot afford experimental transitions.

Inadequate valuation of ecosystem services

Though legumes reduce reliance on fertilizers and enhance agroecosystems health, these services are barely monetized. Market incentives overwhelmingly reward yield rather than sustainability, making it financially unrewarding to prioritize legume-based diversification. Efforts to internalize these ecosystem services into payment systems (e.g., carbon markets, biodiversity-nature credits) are still nascent and fragmented.

4. Institutional and Policy Barriers

Policy misalignment

Despite recent reforms, agricultural policy frameworks such as the EU's Common Agricultural Policy (CAP) continue to favor monocultures and cereal-dominated systems. There is insufficient support for intercropping, crop diversification, or transitioning to legume-rich rotations. Moreover, agri-environmental schemes often overlook the multifunctionality of legumes.

Weak value chains

A major bottleneck lies in the underdeveloped infrastructure for legume processing and distribution. Farmers lack access to reliable markets, storage facilities, and processing units tailored to legumes. In mixed cropping systems, technical hurdles such as harvesting and separating different crops further raise operational costs.

5. Cultural Resistance and Social Barriers

Farmer reluctance

Adopting legumes often requires a shift in mindset, away from high-input, yield-maximizing systems to more regenerative models. Many farmers are unfamiliar with managing legumes or distrustful of their profitability, especially when institutional support is lacking.

Consumer preferences

Consumer demand for legume-based foods remains modest in many regions, driven by dietary habits and limited awareness of their environmental benefits. This affects market development, which in turn feeds back into farmer hesitancy.

6. Strategic Recommendations

Actions	Examples
Promote transdisciplinary research	Fund long-term, multi-scalar studies capturing the ecological and economic benefits of legumes. Support plant breeding programs focused on resilience traits, such as drought tolerance and pest resistance.
Revise policy incentives	Integrate legume-inclusive practices into subsidy schemes and agri-environmental payments. Recognize ecosystem services (e.g., carbon sequestration, biodiversity, soil health) in agricultural reward systems.
Strengthen extension services	Develop tailored agronomic guidelines and toolkits for diverse legume systems. Facilitate peer-to-peer learning and demonstration farms.
Invest in value chain infrastructure	Support cooperatives and SMEs to develop local processing and storage solutions. Create public–private partnerships to boost marketing and branding of legume-based products.
Raise consumer awareness	Promote dietary shifts toward legumes through public campaigns. Highlight environmental and health benefits on product labeling.

Conclusion

Legumes can transform agricultural landscapes by enhancing ecological sustainability, reducing input dependency, and supporting food security. However, systemic barriers continue to prevent their full integration. To valorize their ecosystem services, we must move beyond short-term yield metrics and adopt a holistic approach that combines science, economics, policy, and cultural change. Doing so will not only benefit farmers but also safeguard ecosystems for future generations.

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Cover crops and their benefits to specific following crops

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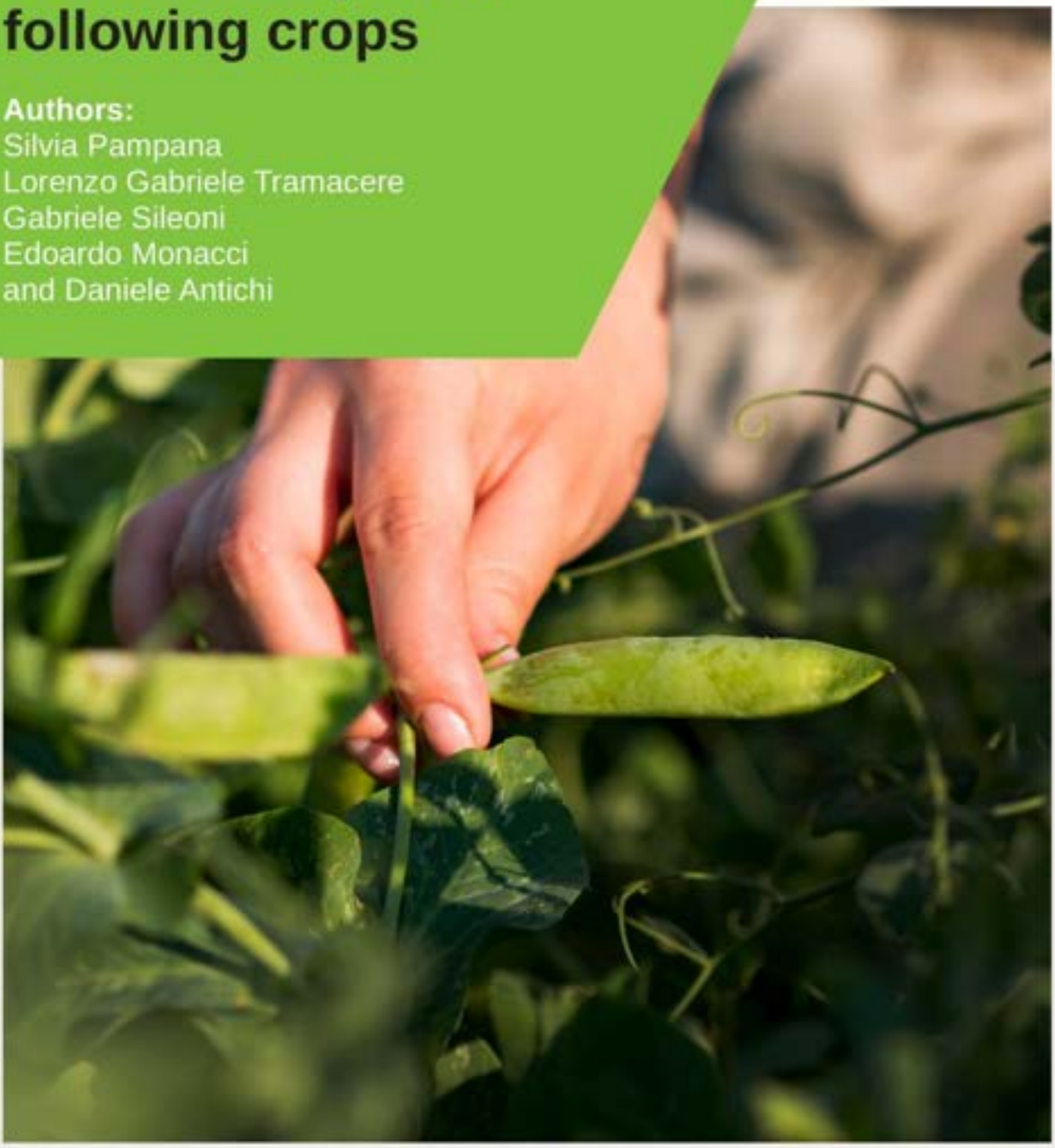

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Summary

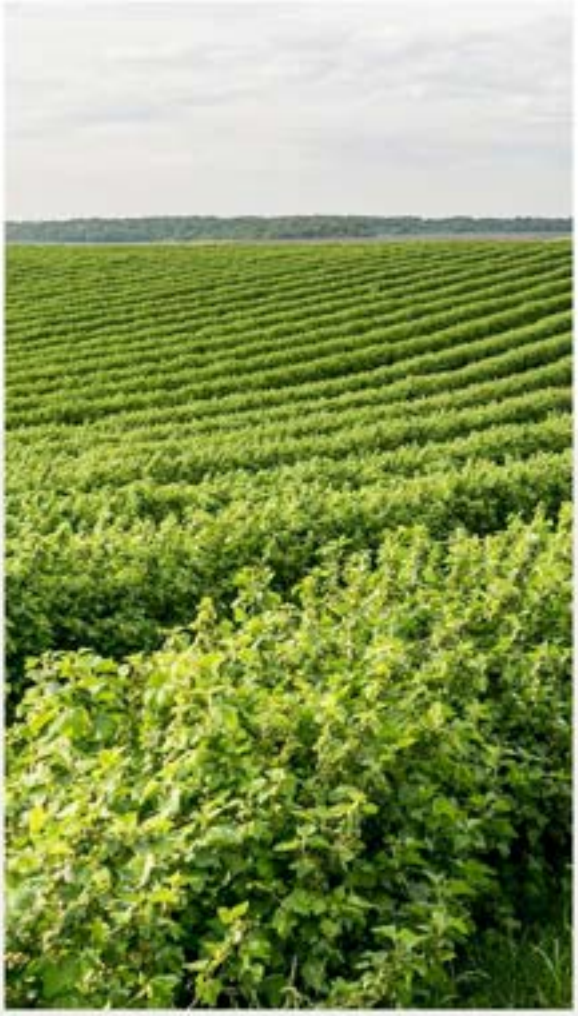
Cover crops—plants grown without the intention of harvesting, typically planted between or alongside cash crops—provide numerous agronomic, environmental, and economic benefits. This white paper examines the influence of key legume cover crops on subsequent plantings of winter (such as wheat and barley) and spring (i.e., maize, and sorghum) cereals, spring crops (sunflower), vegetables (like tomato, and eggplant), and legumes (such as soybean and common bean). We integrated findings from scientific research, farmer experiences, and extension services to provide practical recommendations tailored to each crop sequence.

INTRODUCTION

Rotated crops that are grown not as the primary cash crop but to offer benefits to the cropping system are called "cover crops" (CCs); they can also be named "catch crops", "green manures", "dead mulch" or "living mulch" to more specifically distinguish among their different functions and management: i.e., catch crops are grown to absorb available nitrogen in the soil and prevent nutrient loss; green manures improve soil by incorporation of fresh biomass (organic matter, OM) and nutrients; dead mulches originated from not incorporating dead cover crop material into the soil provide season-long soil cover and protect from weed infestation and excessive water evaporation; living mulches grow together the main crop at least for part of its cycle. According to the Basic Payment Scheme's (BPS) greening rules, catch crops must be planted by 31st August and kept until 1st October, while cover crops should be planted by 1st October and retained until 15th January of the following year. Although cover crops have traditionally been viewed as an ancient practice, their integration into contemporary cropping systems is increasingly recognized as a valuable ecological intensification strategy to enhance soil health, facilitate nutrient cycling, control erosion, suppress weeds and pests, and support biodiversity. The benefits of using cover crops in crop rotations depend on the cover crop type, the timing and the method of termination, with legume cover crops (LCCs) providing an additional advantage thought biologically fixed atmospheric nitrogen (N). This white paper explores the agronomic, economic, and environmental benefits of integrating LCCs into crop rotations, with a specific focus on how they enhance the productivity and resilience of subsequent cash crops.

Which are the most common LCCs and what benefits do they bring?

LCCs can supply additional N through biological nitrogen fixation (BNF) from the atmosphere.



The most used LCCs can be included into different types and are summarized in Table 1 and their characteristics and management reported in Figure 1. Their benefits depend on factors such as species, field conditions, and the duration of cover crop growth. LCCs enhance agricultural systems by fixing atmospheric nitrogen, generating organic matter, enhancing soil structure through their taproot systems, reducing erosion, attracting beneficial insects, and improving soil health. This includes raising organic carbon levels by 0.3–1.5% over 3–5 years, enhancing aggregate stability, and reducing compaction. They also reduce nitrate leaching by up to 60%, mobilise soil P through acid rhizodeposition and acting as mycorrhizal fungi host plants, and sequester significant amounts of carbon (approximately 0.3–1 t C ha^{-1} year-1). Additionally, cover crops offer economic benefits, such as decreased fertilizer and herbicide requirements, yield increases of around 4–8%, and improved resilience (Table 2). However, the sowing and establishment of small-seeded legumes require careful planning, and certain species may interfere with other legumes used in the rotation with negative effects, such as increased pest and disease presence, rotational conflicts, weed issues, and higher costs.

Do the above benefits from LCCs translate into increased crop yields?

The direct economic benefits can be simply evaluated through enhancements in the yield of subsequent crops, as the following examples show (Figure 2). However, it is important to note that yield improvements may sometimes become apparent later in the crop rotation cycle, requiring repeated use of cover crops and that cover crops offer further advantages for both the farm and the environment as well (see previous paragraph).

Winter Cereals (Wheat and Barley)

Positive impact on wheat crop yield while a negative impact on barley crop yield was observed.

Cover crops: hairy vetch

Benefits:

- Vetch adds ~40–80 kg N/ha to-soil, reducing N-fertilizer need.
- Hairy vetch mulch can increase main crop disease resistance and prolong leaf photosynthesis of the following crop.
- No effect on the grain or N yield of the subsequent barley crop, but reduced N leaching.

Risks:

Excessive biomass may delay planting; careful management of termination. Overwinter mortality, regrowth following mechanical termination resulting in competition with subsequent crops, and rapid mineralization of residues resulting in N losses prior to crop N uptake.

Spring Cereals (Maize and Sorghum)

Various positive effects of LCCs on soil health and subsequent summer crop yields have been observed. These benefits are primarily associated with the quantity of biologically fixed nitrogen supplied, particularly when the following cash crops are grown using no-tillage methods.

For example, hairy vetch can supply biologically approximately 70 to 100 kg ha^{-1}fertilizer N annually to the corn and 125-135 to grain sorghum.

Cover crops: hairy vetch, crimson clover, squarrosum clover, faba bean

Benefits:

Vetch adds on average 40–80 kg N ha-1 to-soil, reducing N-fertilizer need

Risks:

Excessive biomass may delay planting; careful management of termination.

Spring Crops (Sunflower)

In France sunflower's performances were negatively affected by LCCs, because of competition for water and poor weed control due to no hoeing.

Cover crops: alfalfa, purple vetch and legumes mixture

Benefits:

average amount of nitrogen returned to soil after cover crops destruction was of 40 kg N/ha for purple vetch, 18 kg N/ha for alfalfa and 19.5 kg N/ha for legumes mixture

Risk:

sunflower suffered of reduced water availability and weed control.

Vegetables (Tomato and Eggplant)

In Italy, squarrose clover was a suitable winter cover crop for tomato, especially in no-till systems.

Cover crops: crimson clover, squarrose clover

Benefits:

Clovers provide nitrogen, boosting early-season growth.

The yield, fruit, and straw nitrogen uptake of eggplant were higher after using a hairy vetch cover crop, possibly due to the high residual nitrogen in the soil. A no-tillage strategy is recommended with legume cover crop residues to minimize the risk of nitrogen loss.

Cover crop: hairy vetch

Benefits:

residual N in soil.

Risk:

The nitrogen released from the hairy vetch cover crop in conventional tillage can be lost if not captured by the next crop. Leaving residues as mulch on the soil surface can delay this process.

Legumes (Soybean)

Farmers can expect a 4.9% increase in soybeans after five consecutive years of cover crop use., which can be even higher (+11.6%) in drought years.

Cover crops: winter pea, hairy vetch, mixtures.

Benefits:

- Peas and vetch fix up to ~80 kg N/ha; boost yield potential of soybean by ~5–10%
- Biomass moderates soil moisture and suppresses early-season weeds
- Winter pea cover improved spring biomass and soil N at planting, yielding ~0.3 t/ha more soybean.

Anyway, mixtures of cereals and legumes enhance nitrogen retention, disrupt pest cycles, and diversify microorganism activity. Studies indicate that due to their complementary N acquisition strategies and aboveground structures, these mixtures can outperform monocultures (overyielding). The increased biomass production of these mixtures also improves ecosystem services like weed suppression and nitrogen retention compared to single-species cover crops.

IMPLEMENTATION GUIDELINES

Extension programs, cost-sharing arrangements, and carbon incentive initiatives may encourage the use of cover crops through. Besides, provision of training, region-specific guidelines, and support may be convenient to address management complexity.

Specific useful hints are the following:

1. Cover Crop Selection:

match growth habit and termination timing with cash crop schedule.

- Use regionally recommended cover crops and seeding rates.
- For delayed sowing, choose early maturing varieties or terminate earlier.
- Late sowing of summer species is not a concern due to the mulch's high moisture retention.
- Mix legumes and grasses for nitrogen fixation and residue cover.

2. Termination Techniques:

- Schedule termination to reduce negative effects on soil moisture or planting window.
- In case of green manure, ideal termination 2–3 weeks before cash crop planting to allow for residue breakdown (e.g., allelochemicals), minimum tillage sufficient for incorporation to save soil water.
- Roller-crimping at flowering (e.g., vetch, see Photo 1).
- Mowing or herbicide application but more rapid degradation of the dead mulch

3. Integrated Nutrient Management:

- Sample soil mid-season after cover crop termination.
- Adjust fertilizer N based on cover crop contribution.

4. Monitoring & Adaptive Management:

- Track yields, soil health, and pest/disease presence over time.
- Rotate cover species annually or grow in mixtures to avoid trait fatigue and responsiveness loss.
- Inoculate with Rhizobia in case of first/rare cultivation of legume crops

Conclusion

LCCs are a versatile and sustainable instrument within contemporary cropping systems to achieve with four primary aims: enhancing soil fertility, improving soil structure, managing weeds and pests, and contributing to environmental management.

When tailored to specific crop sequences, they offer substantial agronomic, environmental, and economic returns. The best cover crop species and management depend on the grower's goals; by optimizing selection, timing, and management, their adoption can help farmers in maintaining soil health, high yields, reduce input dependence, and contribute to climate resilience.

Evidence from academic literature and on-farm studies shows that LCCs can significantly reduce fertilizer inputs, improve soil structure and enhance yields, thereby contributing to long-term farm profitability and sustainability.

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ANNEXES

Type	Examples	Main Characteristics and management
Winter annuals	crimson clover	It relatively quickly establishes compared to some longer-term clovers but should be sown early for autumn cover as it does not thrive in cool and heavy soils. Sowing: August; Rate: 30 kg ha^{-1}
	berseem clover	It quickly establishes and forms a dense cover for effective weed suppression; it also regrows rapidly after mowing or grazing. Drought-tolerant, can be grown also as a summer annual in colder climates.
	hairy vetch	Hairy vetch thrives even in hard frost areas, producing ample vegetation and fixing significant nitrogen. Its residues decompose fast when green manured, releasing nitrogen quickly, which benefits high-nitrogen-demand crops. Suitable also to be managed as dead mulch in mixture with grass species. It performs well even on sandy soils, given adequate soil potassium for optimal productivity. Sowing: August-September; Rate: 80-100 kg ha^{-1}
	common vetch	Primarily used for fertility building and grazing. Less suited to drought-prone soils and frost areas than other legumes. Sowing: August-September; Rate: 80-100 kg ha^{-1}
	field peas	Establishes quickly and thrives in cool, moist climates, producing high residue. Primarily used for fertility building, either alone or in mixtures. Suitable for late sowing. Sowing: Late August- mid-September; Rates: 200–400 kg ha^{-1}
	field beans	Most used to increase fertility both as a single species or part of mixtures. They can be sown later than many legumes. Sowing: Late August to September; Rate: 100–200 kg ha^{-1}
Perennials	crown vetch	Suited for well-drained soils and low fertility, providing permanent ground cover but establishing slowly. Best for perennial use.
	red clover	Biannual species, vigorous, shade-tolerant, winter-hardy, and quick to establish. Often inter-seeded with small grains in relay intercropping, its slow initial growth minimizes competition and ensure forage production or green manures in post-harvest season of intercropped cereals.
	white clover	Perennial species, primarily utilized for fertility enhancement, this legume does not exhibit as much growth as many others and has a lower tolerance for drought conditions. Despite its shorter stature, it has better shading tolerance compared to many other legumes. This makes it suitable as permanent living mulch. Sowing: August; Rate: 10-15 kg ha^{-1}
	Sainfoin	A perennial species lasting over four years. It enriches low-nutrient soils and is commonly used in grazing mixtures. It thrives in poor soil and drought conditions. Sowing: August; Rates: 70 kg ha^{-1}
Biennials	Alfalfa	Ideal for well-drained, fertile, near-neutral soils, alfalfa grows quickly and can enhance soil structure over several years. Often inter-seeded with oats, wheat, or barley, it continues to grow after grain harvest. Sowing: August; Rates: 20 kg ha-1
	sweet clover	Winter-hardy and vigorous crop that can help break up compacted subsoils. It withstands high temperatures and drought conditions better than many other cover crops. However, it performs poorly in wet, clayey soils. It requires a near-neutral soil pH and a high calcium level, but it can grow well on low-fertility soils if the pH is high. The plant usually flowers and completes its life cycle in the second year. When used as a green manure crop, it is incorporated into the soil before full bloom. Sowing: August; Rates: 10–15 kg ha^{-1}
Summer annuals	annual species grown in the summer or colder climates	E.g., cowpeas (*Vigna unguiculata*) or sunn hemp (*Crotalaria juncea*), perform better in mixture with grass species (E.g., sudangrass, foxtail millet or grain millet) or other short cycle forbs (e.g., buckwheat). Require irrigation after sowing and early phases in dry climates.

Table 1.

Examples and characteristics of LCCs grouped by different types.

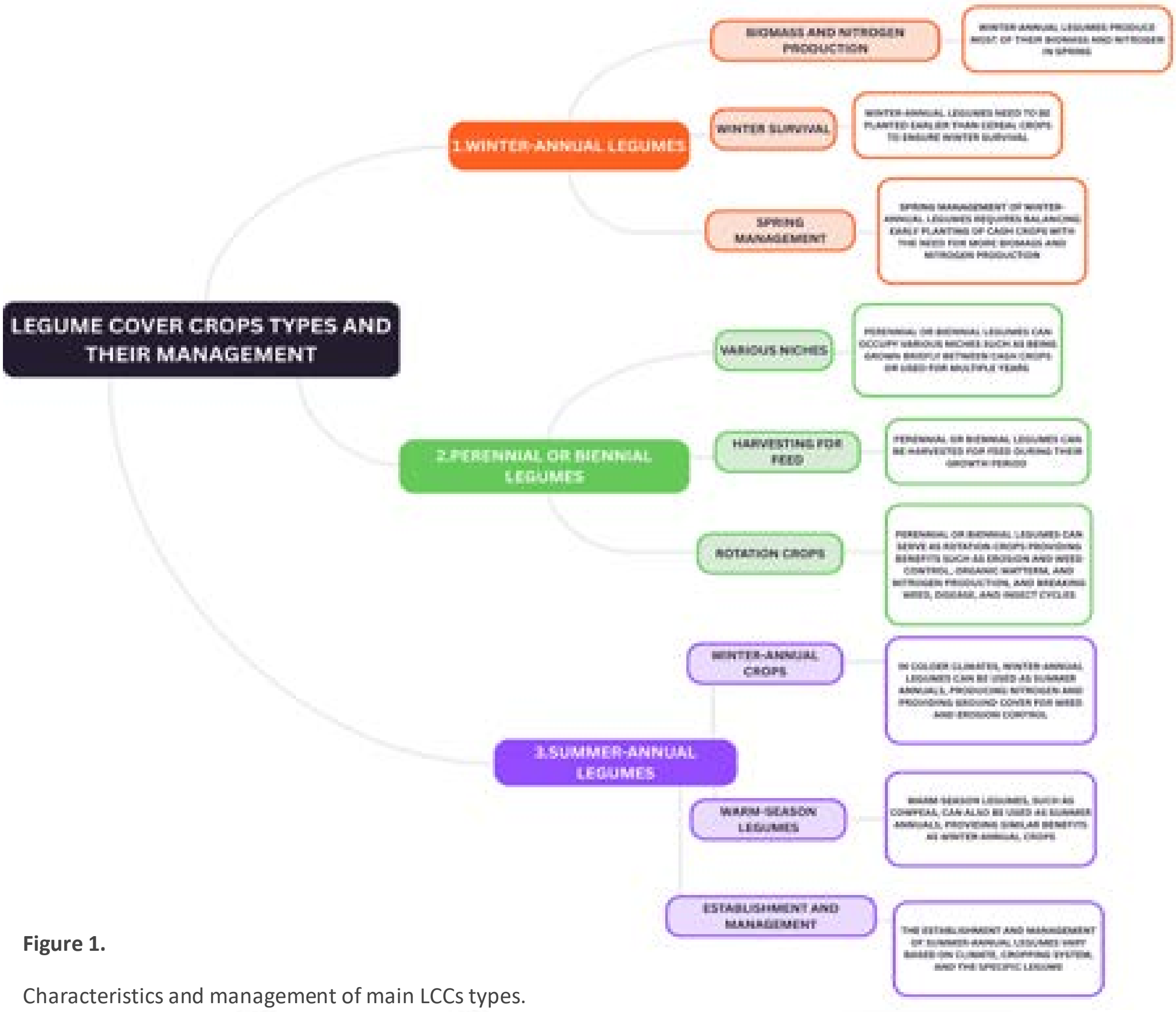

Figure 1.

Characteristics and management of main LCCs types.

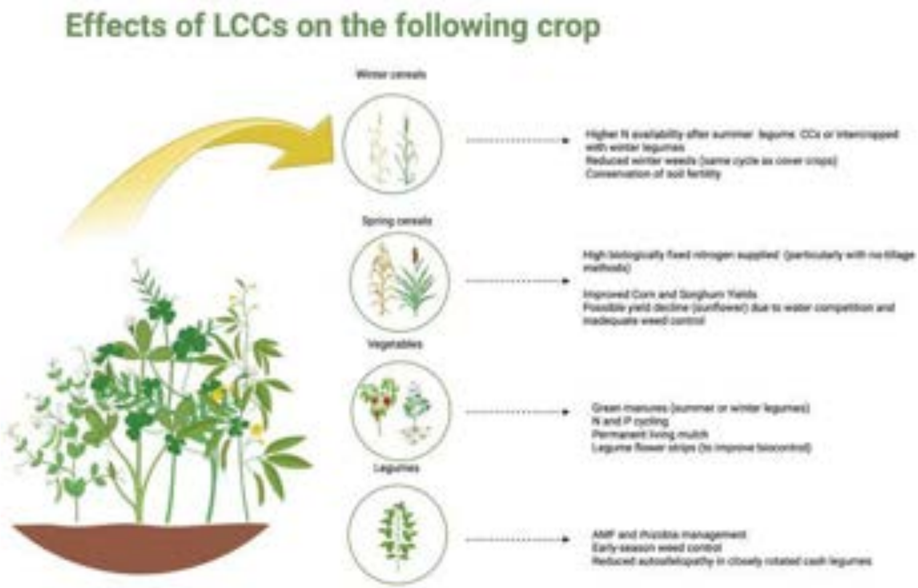

Figure 2.

Effects of LCCs on the following crops. Created in https://BioRender.com

Benefit	Description
Agronomic	
Atmospheric nitrogen fixation, uptake and release	Convert atmospheric N_2 into plant-available nitrogen through symbiosis
Weed suppression	Allelopathic effects (release compounds that inhibit weed germination) and physical competition
Nematode suppression	Generally sensible to nematodes, some cultivars can reduce nematodes populations (e.g., cowpea for root-knot nematode species (*Meloidogyne incognita*); sunn hemp for *Rotylenchulus reniformis*.
Environmental	
Reduce/prevent erosion	Reduced water runoff Improved soil aggregate stability
Soil health and fertility	Soil chemical properties: increasing soil organic matter (+0.3–1.5% C, over 3–5 years); C and nutrient cycling
	Soil physical properties: increased organic matter improves aggregate formation and stability and reduces compaction
	Soil biological properties: increased microbiological and mesofauna biodiversity, promoted microbial activity
Climate Mitigation	Deliver biomass for soil carbon sequestration (~0.3–1 t C/ha/yr) Reduction of CO_2 emissions
Climate Resilience	Increase water infiltration into soil
Biodiversity and habitat provision	Attract beneficial insects (pollinators) and wildlife
Economic	
Forage	Cover crops as additional source of forage (e.g., by grazing on regrowth after mowing)
Economic Gains	Reduced herbicide and fertilizer requirements
	Subsequent crop yield increase (approximately 4–8%) and stability
	Risk reduction (through enhanced resilience)

Table 2.

Potential benefits of LCCs use, with a short description of mechanisms.

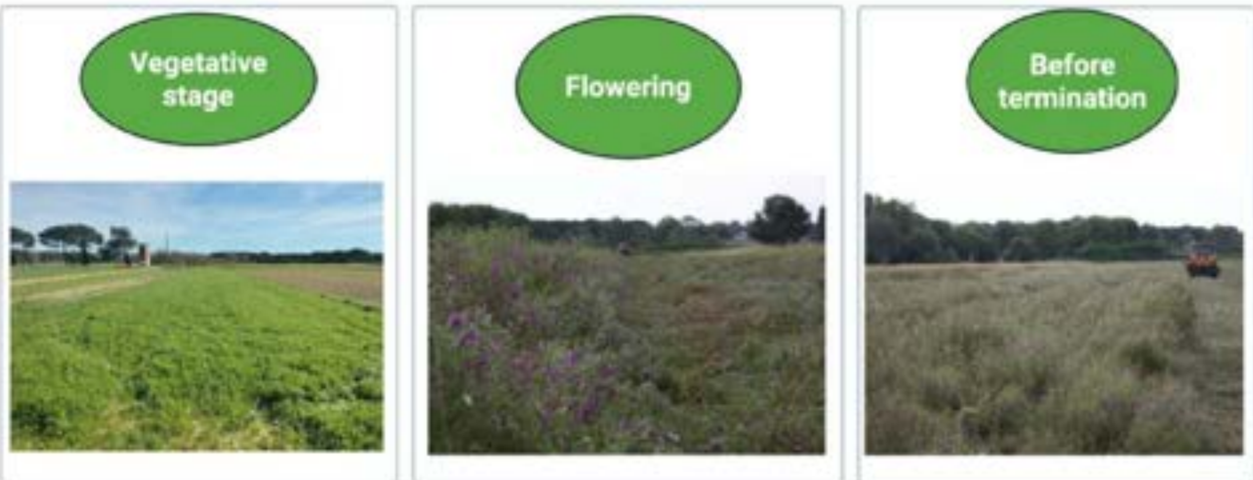

Photo 1.

One of the most used LCCs is Vetch

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Annexes

Annex I: Practice Abstracts at VALERECO EU-CAP Network page

EU CAP NETWORK

PROJECT - RESEARCH AND INNOVATION

VALERECO | Valorization Legume Related Ecosystem Services

PROJECT IDENTIFIER: 2024HE_101135472_VALERECO

Discover website

Innovation, knowledge exchange & EIP-AGRI >

ONGOING | 2024 - 2028

Greece, Italy, France, Spain, Portugal, Netherlands, Germany, Lithuania, Switzerland, North Macedonia, Serbia

Context

VALERECO target is to promote adoption and understanding the value of legume crops towards transition to sustainable, productive, climate-neutral, environment-friendly and resilient farming systems. The project aims to quantify and enhance the environmental and economic value of ES provided by 4 minor or underutilized and 8 major legume crops. It seeks to encourage diversification of farming practices throughout the EU and Associated Countries, which can contribute to healthier and sustainable diets and climate change resilience. The identification will be achieved through: (1) a thorough analysis on the ecosystem-services legacy and (2) the investigation of gateways for penetration of legumes and their associated ES to the new CAP. The valorization will be implemented through the establishment of nine Living Labs (LLs) to conduct: (1) behavioural design strategies to promote the adoption of legumes in production and consumption, (2) on-station participatory trials to assess the performance of major and minor-underutilised legume crops in diversified farming systems, (3) to demonstrate and co-create technical economically and environmentally assessed solutions for legumes inclusion in cropping systems. The dissemination will be realized through: (1) the development of a Digital Legume Information Hub (DLIH) to upscale and maximize the uptake of VALERECO's results, (2) the development of a Decision Support System (DSS) to support the decision-making of farmers and advisors for legumes adoption, and (3) the generation of capacity building material made available to the public through an E-learning Platform.

Objectives

VALERECO focuses on promoting sustainable agricultural practices through the adoption of legume crops. Its key objectives include:

- **Enhancing Legume Adoption**: Encourage the use of legume crops to develop sustainable, productive, and climate-resilient farming systems across Europe.
- **Quantifying Ecosystem Services**: Assess the environmental and economic benefits provided by both major and underutilized legume crops, promoting diversification in farming practices.
- **Stakeholder Engagement**: Involve a broad range of stakeholders to maximize interaction and ensure research outcomes are widely adopted.
- **Knowledge Dissemination**: Share scientific and technical knowledge through an E-learning platform and other channels, enabling stakeholders to effectively utilize research findings.
- **Feedback Mechanism**: Gather stakeholder feedback to align project outputs with user needs, ensuring relevance and practicality.
- **Integrated Activities**: Align dissemination, communication, and exploitation efforts to ensure sustainability and reusability of results.
- **Fostering Synergies**: Create synergies with other projects to enhance impact through shared networks and collaborative initiatives.
- **Establishing Living Labs**: Set up nine Living Labs for participatory trials that evaluate legume crop performance in diverse farming systems, co-creating solutions for their integration.
- **Exploitation Strategy**: Develop a robust strategy to identify commercial and non-commercial pathways for utilizing project results, ensuring sustainability beyond the project's duration.

These objectives aim to facilitate a transition towards sustainable agriculture while addressing climate change resilience and promoting healthier diets in Europe.

Activities

VALERECO engages in a variety of activities designed to promote the adoption of legume crops and enhance sustainable agricultural practices across Europe.
Key activities include:

- **Research and Trials**: Conducting extensive research on both major and underutilized legume crops through field trials and experiments to assess their environmental and economic benefits. This includes evaluating their role in improving soil health, biodiversity, and overall farm productivity.
- **Establishment of Living Labs**: Setting up nine Living Labs where farmers, researchers, and stakeholders collaborate in participatory trials. These labs serve as experimental platforms to test innovative practices, share knowledge, and develop solutions tailored to local farming conditions.
- **Stakeholder Engagement Workshops**: Organizing workshops and seminars to engage farmers, agronomists, policymakers, and industry representatives. These events facilitate dialogue, knowledge exchange, and the co-creation of strategies for legume integration into existing farming systems.
- **Knowledge Dissemination**: Developing an E-learning platform and various communication materials (e.g., brochures, videos) to disseminate research findings and best practices. This ensures that stakeholders have access to valuable information on legume cultivation.
- **Feedback Collection**: Implementing mechanisms to gather feedback from stakeholders regarding the project's outputs. This helps in refining tools and resources to better meet user needs.
- **Synergy Building**: Actively collaborating with other related projects and initiatives to share insights, resources, and networks, enhancing the overall impact of VALERECO's efforts.
- **Exploitation Planning**: Creating an exploitation strategy that identifies pathways for commercializing research results and ensuring their sustainability beyond the project's lifecycle.

Through these activities, **VALERECO aims to foster a shift towards more sustainable agricultural practices while addressing challenges related to climate change and food security in Europe**.

Project details

Main funding source

Horizon Europe (EU Research and Innovation Programme)

Type of Horizon project

Agro-ecology > Arable crops > Biodiversity and nature > Organic farming >

Resources

Links

- VALERECO on Facebook
- VALERECO on LinkedIn
- VALERECO on X (Twitter)
- VALERECO on Bluesky
- VALERECO on YouTube

Funded by the European Union

5 Practice Abstracts

1. Cover crops and their benefits to specific following crops

Reducing high fertilizer costs, improving soil health, and increasing farm resilience are common goals for agricultural practitioners. Legume cover crops (LCCs) offer a practical and sustainable solution to enhance cropping systems. This practice provides an opportunity to naturally fertilize the soil and suppress weeds, directly increasing the productivity and profitability of primary cash crops.

These plants naturally capture nitrogen from the atmosphere, supplying the soil with **40–80 kg of free nitrogen per hectare** and drastically cutting fertilizer needs.

Integrating LCCs like vetch, clover, or peas into crop rotations provides significant benefits. This practice improves soil structure and water retention, leading to **cash crop yield increases of around 4–8%**. For instance, studies show soybean yields can increase by nearly 5% after five years of cover crop use, and by over 11% in drought years. While proper management is key—as outcomes can vary between crops like wheat (positive) and sunflower (risk of water competition)—the long-term improvement in soil health and farm productivity is consistently positive.

LCCs can be implemented on-farm with straightforward management. The primary costs are for seeds and planting, but the return on investment is substantial.

- Implementation leads to lower fertilizer and herbicide bills, higher and more stable yields, and healthier soil that holds more water during dry spells.
- **To legume cover crops**:
    1. **Select the Right Mix**: Choose LCCs (or a mix of legumes and grasses) suited to the specific region and main crop schedule.
    2. **Time Termination**: The cover crop should be terminated 2–3 weeks before planting the cash crop to allow the green manure to break down.

Adjust Inputs: After termination, soil testing is recommended to adjust and reduce fertilizer applications, thereby capitalizing on the natural nitrogen boost.

2. Overcoming Barriers to Valorizing Legume Ecosystem Services

VALERECO explores several operational, agronomic, social, economic, institutional and cultural barriers that prevent farmers from taking full advantage of legumes. While crops like beans, peas, and lentils can reduce fertilizer costs and build healthier soil, many growers are held back by challenges such as unstable yields, high start-up costs, a lack of practical knowledge, and poor access to markets. The goal is to make growing legumes a bit more sustainable and an attractive choice for integration in diversified farming systems.

Results

VALERECO is working on a strategic roadmap for making the use of legumes more attractive for production and consumption. Key solutions involve among others:

- promoting new breeding programs for resilient and better performing legume varieties,
- better fitted legume varieties suited to diverse farming systems and adapted to ongoing climate change repercussions,
- advocating for new policies that financially reward farmers for the environmental benefits they provide, such as improved soil health and carbon storage
- incentivizing the wide use of legumes in healthy diets by involving consumers and other actors across the agrifood value chains into co-created transformation pathways

Practical recommendations for end-users

Integrating legumes into rotations can significantly decrease reliance on expensive nitrogen fertilizers and the implementation of unsustainable and harmful agricultural practices. Over time, legume-based diversification leads to healthier, more drought-resistant farms and more stable, long-term productivity for the entire agricultural holding. The primary benefits for producers constitute lower input costs and a surge of ecosystem services such as pollination, water retention, and soil health, especially when combined with conservation tillage and other nature positive agricultural practices. While there may be initial investments in new seeds and training, adoption can begin on a small scale. Farmers can benefit from con

3. The role of legumes in sustainable crop rotation

Continuously sowing cereal crops like wheat on the same land presents significant challenges for farmers. This practice, known as monoculture, leads to higher costs due to an increased need for nitrogen fertilisers and plant protection products. It also creates long-term problems with recurring weeds, pests, and diseases that become harder and more expensive to manage over time. This project addresses the opportunity to break this costly cycle by introducing a simple, sustainable, and profitable alternative.

An important solution is to integrate leguminous crops, such as peas, into the rotation. Long-term experiments have proven that this strategy delivers multiple benefits. By alternating between cereals and legumes, farmers can naturally disrupt the life cycles of persistent weeds, pests, and diseases that thrive in monoculture systems. Most importantly, legumes have the unique ability to fix atmospheric nitrogen in the soil, providing a natural source of fertiliser for the next crop and significantly reducing the need for synthetic fertilisers.

Farmers can directly apply these findings to improve their bottom line and farm health.

- Sowing a legume crop like peas before wheat can boost the subsequent wheat yield by as much as **17%**.
- This rotation with legumes can lead to direct cost savings, reducing the need for nitrogen fertiliser by an average of **40 kg per hectare** in the following crop.
- Crop rotation also serves as an effective tool for integrated pest and weed management, decreasing reliance on chemical sprays and lowering the risk of herbicide resistance.

The primary step is to diversify the crop plan to include a legume in a rotation. This makes the entire farming operation more resilient and sustainable. By reducing input costs while increasing yields, rotating with legumes is a powerful strategy to enhance farm profitability.

4. Soybean production in the system of winter cover crops

VALERECO aims to find a practical way for farmers to **improve soybean yields** in challenging, semi-arid conditions. The goal is to increase productivity and meet the growing demand for plant protein, all while making farming more sustainable and **reducing the need for chemical fertilisers**.

The IFVCNS team tested an effective solution: planting **winter peas as a cover crop** before the main soybean crop.

This method was proven to **significantly boost soybean yields**. It works by enriching the soil with beneficial microbes and naturally adding nitrogen, a key nutrient for soybeans. The study confirmed that this is a practical and beneficial system for soybean production.

Practical Advice for Farmers

This strategy offers direct benefits on the farm. By planting **winter peas**, growers can expect the following benefits:

- **Higher Yields:** The most important result is a bigger, better soybean harvest.
- **Lower Costs:** The peas naturally "fix" nitrogen from the air into the soil, cutting down on the need to buy expensive nitrogen fertilisers.
- **Healthier Soil:** This practice improves the soil's structure, reduces compaction from machinery, and helps suppress weeds naturally.

Keep in Mind:

- There is an **initial investment in the cover crop seed and the labour** for planting and later terminating it.
- To get the best results, the **cover crop must be terminated at the right time** so it doesn't compete with the soybeans for water or nutrients.

The choice of cover crop and management plan should be **tailored to the farm's specific soil type and climate**.

5. Intercropping with legumes to improve productivity and soil health

VALERECO aims to address a wide range of modern agriculture challenges through the introduction of legumes in diversified cropping systems with emphasis on sustainable and effective intercropping schemes. The proposed intercrops aim to increase crop yields and farm profitability while reducing inputs, costs and environmental risks.

Specifically, legumes, as for example peas, clovers, lentils, chickpeas etc., are combined with cereal cultivation to create functional intercrops and achieve optimal land use efficiency. Soil nitrogen enrichment through legume nitrogen fixation is a prominent benefit of such legume-cereal intercrops. In addition, the simultaneous presence of crops with different functional characteristics in the same field for a while, leads to optimal resource exploitation, due to the complementarity of resource use by the intercropped plants.

There are four types of intercropping : mixed-intercropping (both crops in the same row), strip-intercropping (alternate crops strips), row-intercropping (alternate crop rows), , and relay intercropping (crops co-exist for a while). Implementing this strategy can offer:

- **Environmental Benefits:** Over time, the soil will become healthier with better structure, improved water retention, and natural weed suppression, securing the future productivity of your land. For livestock operations, intercropped forage also offers higher protein content. Legumes contribute to more resilient agroecosystems that are better able to withstand climate variability and disturbances.
- **Economic Benefits:** The most immediate benefit is a significant reduction in fertilizer and chemical pest and weed control inputs. .

To summarize, although important challenges should be addressed to their wide adoption in the new era of agriculture, legume-based intercropping systems offer a sustainable and effective approach to improving low-input agroecosystems and promote higher productivity and profitability compared to monocultures.

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