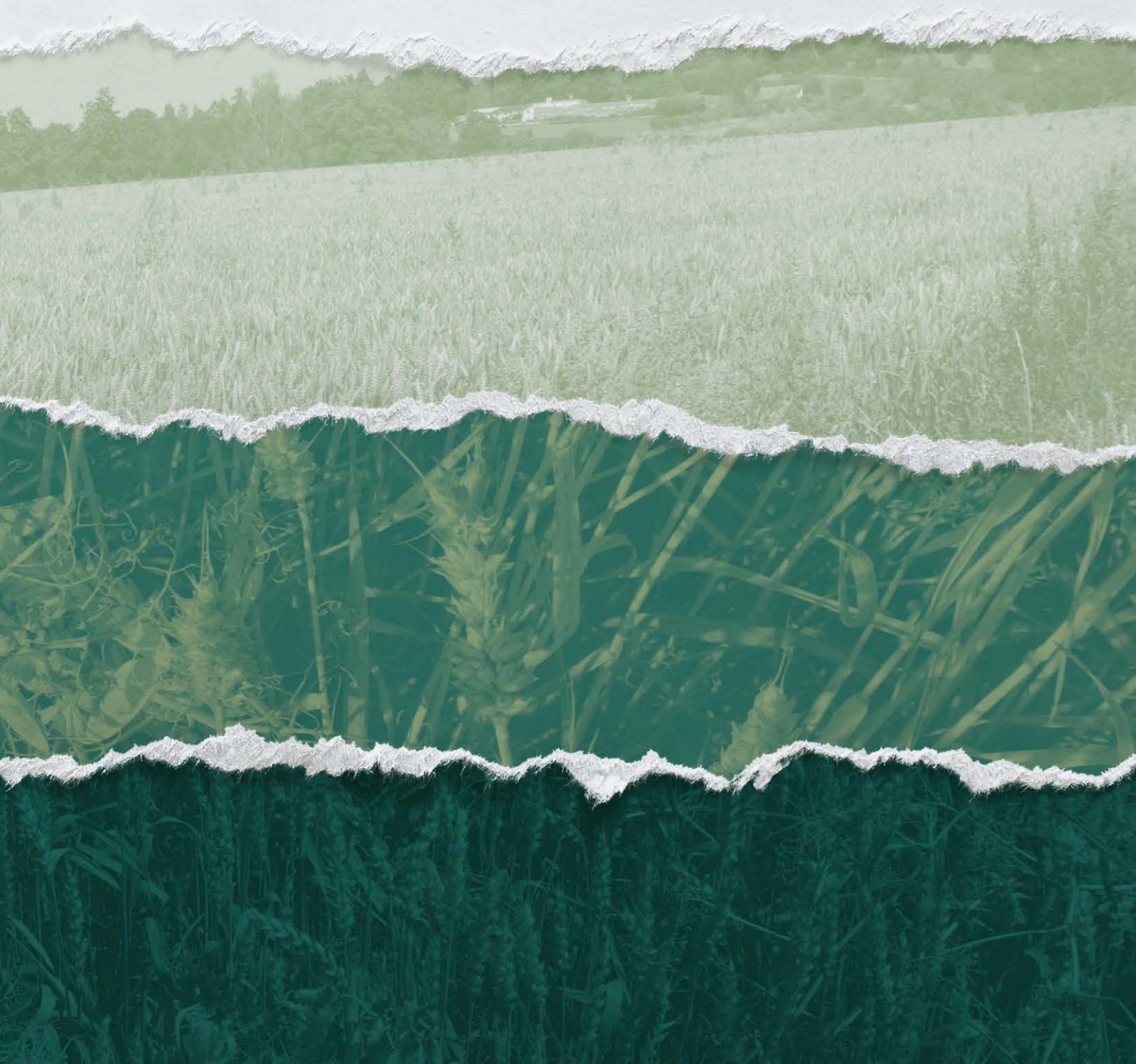




LEGUMINOSE

Best Practice Booklet

Published in September 2026







European agriculture faces a growing number of challenges. Farmers are dealing with rising input costs, increasing weather extremes, pressure to reduce environmental impacts and growing demands for food sustainability and security. At the same time, many farming systems have become increasingly specialised, often relying on monocultures, a limited number of crops and external inputs.

Legumes have an important role to play in addressing these challenges. Crops such as peas, fava beans, lupins, lentils and chickpeas can provide high-quality protein for food and feed while reducing dependence on mineral nitrogen fertilisers. Legumes also contribute to crop diversification and can support soil fertility and biodiversity.

Despite these benefits, legumes still occupy a relatively small share of European arable land. One reason is that legume production can be less predictable than cereal production. Yields may vary considerably between years and growing conditions, making farmers reluctant to include legumes in their cropping systems.

Cereal–legume intercropping offers one way to overcome some of these challenges. By growing cereals and legumes together in the same field at the same time, farmers can combine the strengths of both crop groups. Well-designed intercrops can improve resource-use efficiency, stabilise yields, reduce production risks and contribute to more diverse farming systems.

This booklet brings together practical knowledge, farmer experiences and scientific evidence from the LEGUMINOSE project. It provides an evidence-based introduction to cereal–legume intercropping.

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Introduction

Introduction

What cereal–legume intercropping is

Cereal–legume intercropping is the practice of growing a cereal crop and a legume crop together in the same field at the same time. Instead of cultivating each crop separately, farmers combine two species that can complement one another in their use of resources and their response to environmental conditions.

Common cereal partners include wheat, barley, oats, rye and triticale. These can be combined with legumes such as peas, fava beans, lupins, lentils or chickpeas, depending on local growing conditions and farm objectives.

Intercropping differs from crop rotation. In a crop rotation, different crops are grown one after another in the same field over a sequence of years. In an intercrop, plant species grow simultaneously and interact throughout the growing season.

These interactions are at the heart of intercropping. For example, cereals rely on nitrogen from soil resources or fertilisers, while legumes can obtain the larger part of their nitrogen through biological nitrogen fixation. Because legumes depend less on soil nitrogen, more of the available soil nitrogen remains accessible to

the cereal, reducing direct competition between the two crops. Furthermore, cereals generally have fibrous, shallow root systems that drink from the upper soil layer. Legumes, on the other hand, tend to have deep taproots that reach down into deeper moisture reserves. Because the two crops use resources differently, they often compete less directly than two crops of the same species and can sometimes use available resources more efficiently when grown together.

Depending on the crop combination and local conditions, intercropping can contribute to higher resource–use efficiency, more stable yields, reduced pest and disease pressure, greater biodiversity and improved resilience to environmental stress.

Not every crop combination is equally successful. Species choice, soil conditions, climate, management practices and the intended use of the harvest all influence performance.

Understanding these factors is essential for designing intercrops that work under local farm conditions.

A practice with a long history

Cereal–legume intercropping is not a new idea. Evidence of cereals and legumes being grown together dates back to the Middle Bronze Age (around 2000–1600 BC), and similar practices have been documented throughout agricultural history in many parts of the world. Farmers recognised that different crop species often complemented one another, allowing them to make more efficient use of light, water and nutrients while reducing the risk of complete crop failure. For centuries, cereal–legume mixtures formed part of farming systems adapted to local climates, soils and available resources.

During the twentieth century, intercropping became less common as agriculture became increasingly

specialised. Advances in plant breeding, mechanisation, mineral fertilisers and crop protection products encouraged the development of monoculture systems that simplified crop management and harvesting. As a result, cereal–legume mixtures largely disappeared from mainstream arable farming in many regions.

Today, interest in intercropping is growing again. Rising fertiliser costs, increasing weather variability, concerns about biodiversity loss and the need for more sustainable farming systems are encouraging farmers, advisors and researchers to revisit this long-established practice.



Modern machinery, improved crop varieties and a better understanding of plant interactions now make it possible to adapt intercropping to a wide range of farming systems, from organic mixed farms to conventional arable enterprises.

Rather than representing a return to the past, modern cereal–legume intercropping combines traditional knowledge with contemporary agronomic research and presents a farming system for improving productivity, resilience and sustainability under changing climatic conditions.

About LEGUMINOSE

While the principles of intercropping are well known, many practical questions remain. Which crop combinations perform best under different conditions? How should intercrops be managed? What benefits can farmers realistically expect? And what barriers still limit wider adoption?

The LEGUMINOSE project was established to address these questions. Bringing together farmers, researchers, advisors and value-chain actors, the project explored cereal–legume intercropping across a wide range of farming systems and environmental conditions.

The project established a network of 189 Living Labs across Europe, complemented by research field trials designed to investigate intercrop performance in greater detail (Figure 1). Together, these activities covered a wide range of climates, soils and management

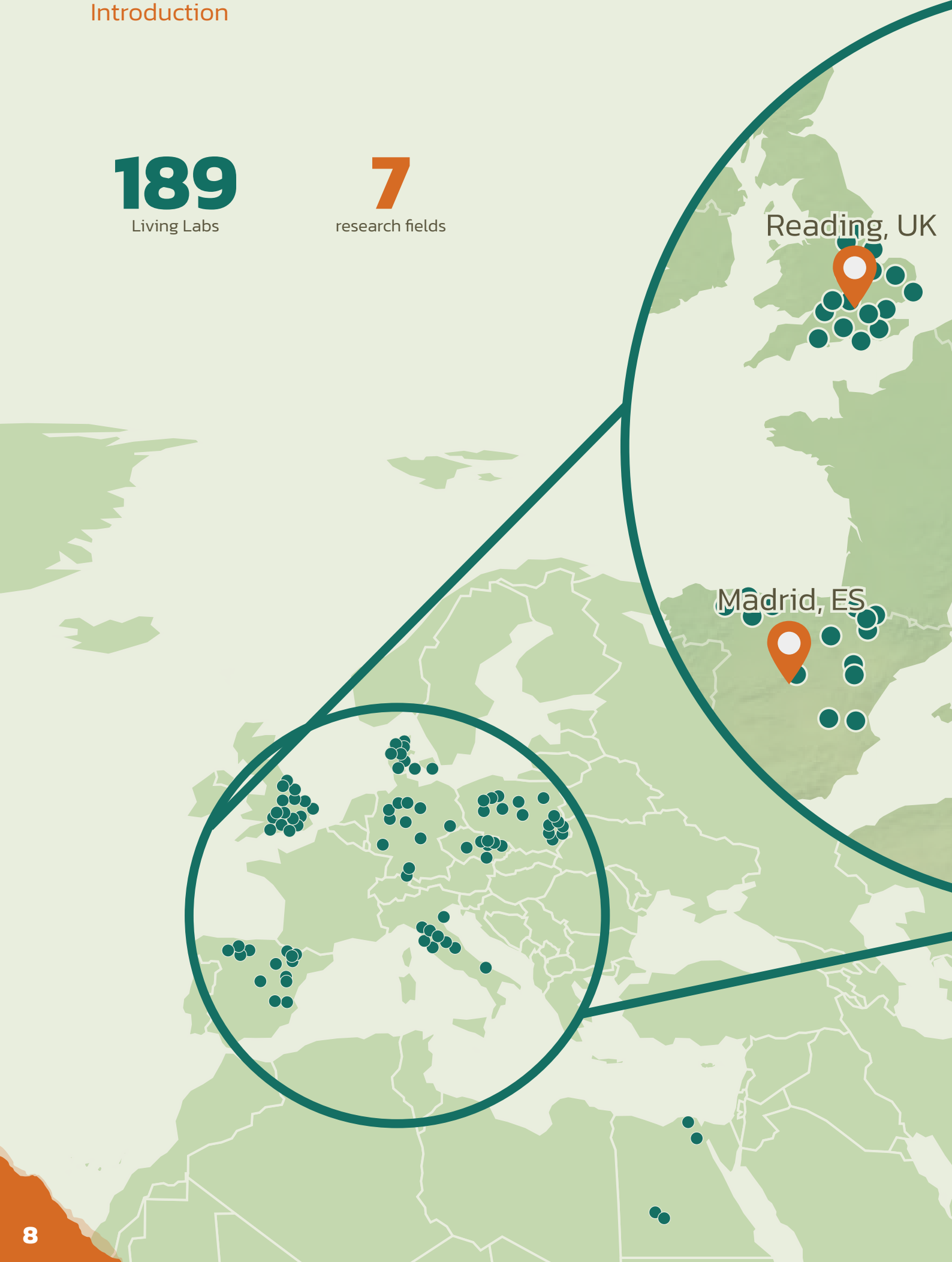
systems, from Mediterranean and continental regions to oceanic and arid environments.

Farmers tested approximately 40 different cereal–legume combinations under practical farming conditions, while 13 additional combinations were evaluated in research trials. This combination of on–farm experience and scientific experimentation provided valuable insights into how intercrops perform in different contexts and how they can be adapted to local conditions.

The examples and findings presented throughout this booklet draw on this collective experience. They combine scientific evidence with practical knowledge from farmers and other stakeholders involved in the project.

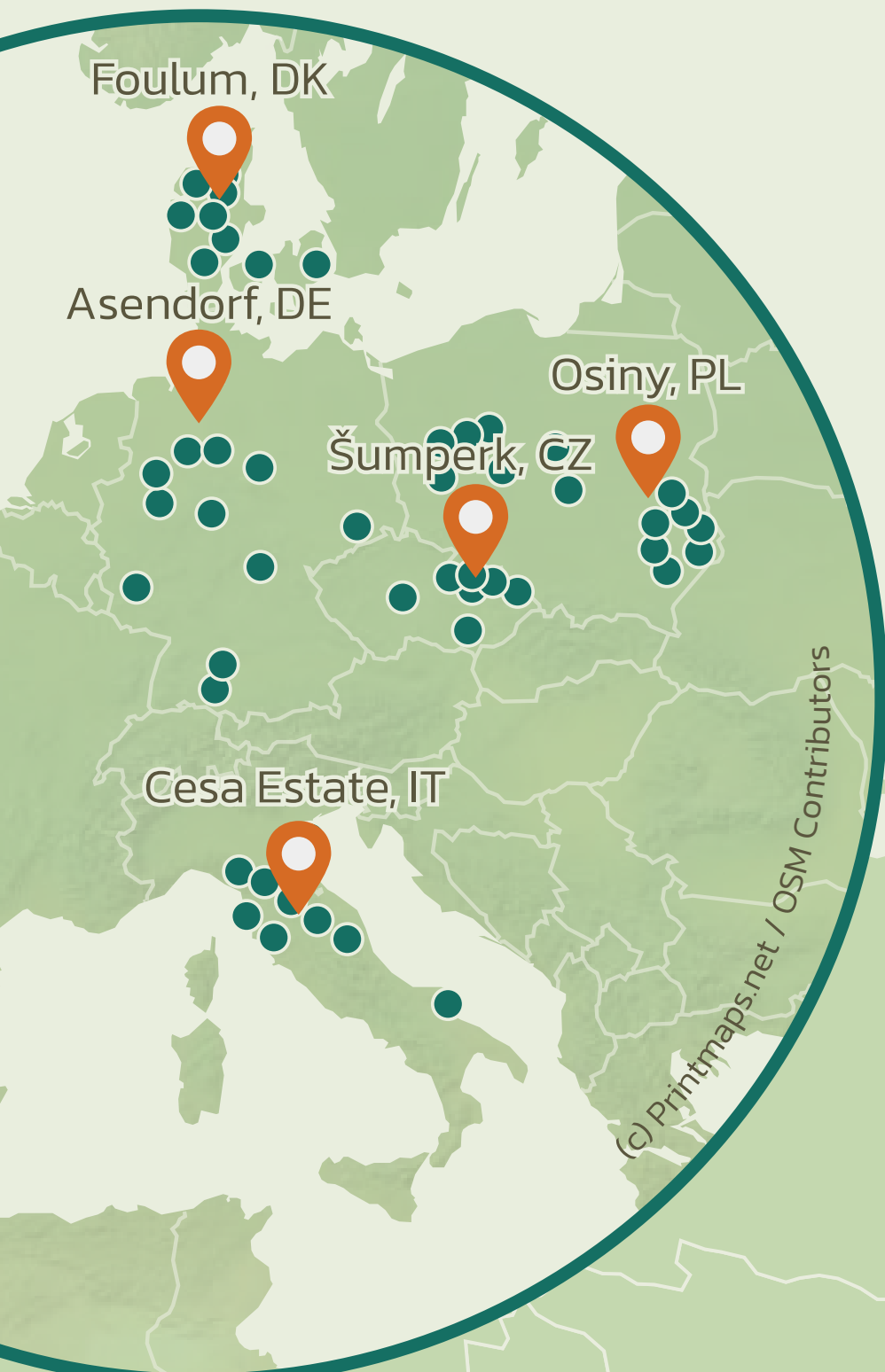
189
Living Labs

7
research fields





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LEGUMINOSE at a glance

- 189 Living Labs
- Research field trials across Europe
- Multiple climate zones and farming systems
- Around 40 intercrop combinations tested on farms
- Farmers, researchers and value-chain actors working together

Introduction

How to use this booklet?

This booklet provides an evidence-based introduction to cereal–legume intercropping. It brings together practical experience from the LEGUMINOSE Living Labs and scientific evidence from the LEGUMINOSE research field trials to support informed decision-making about intercropping.

Because farming conditions vary widely, there is no single recipe for successful cereal–legume intercropping. The most suitable crop combinations and management approaches depend on local climate, soil conditions, available machinery, markets and individual farm objectives. Rather than providing prescriptive recommendations, this booklet presents the key principles, practical experiences and research findings that can help readers evaluate whether intercropping is suitable for their circumstances and identify approaches worth testing under local conditions.

The booklet begins with guidance on designing and establishing cereal–legume intercrops. The following chapters explore the agronomic, environmental and ecological benefits of intercropping, drawing on results from the LEGUMINOSE Living Labs and research field trials. The later chapters then examine practical aspects of adopting intercropping on farms, including economic performance, post-harvest options, market opportunities and common barriers to adoption. The final chapters introduce decision-support tools, discuss the wider policy environment and present key recommendations for farmers, advisors and policymakers.

Intercropping is best approached as a learning process. This often involves starting with small-scale trials, comparing outcomes with existing systems and gradually refining management practices based on observed results and local conditions.



LEGUMINOSE

Designing and establishing a cereal–legume intercrop

Designing and establishing a cereal–legume intercrop

Successful intercropping begins long before the crop is sown. Rather than relying on a fixed recipe, successful intercrop design involves a series of connected decisions: defining the purpose of the intercrop, selecting compatible crop species, choosing an appropriate intercropping system, establishing the crop successfully and planning how the harvest will be used. Each decision influences the next, and together they determine how well the intercrop performs.

The experiences from the LEGUMINOSE Living Labs show that successful intercrops are not necessarily those with the highest yield potential. Instead, they are systems that are well matched to local conditions, farm objectives and available resources.

Starting with a clear objective

Before selecting crop species or sowing methods, it is important to define why the intercrop is being established. Cereal–legume intercropping can be designed to meet different objectives. Some aim to improve yield stability or reduce production risks. Others want to reduce fertiliser requirements, improve weed suppression or long-term soil fertility, produce home-grown feed or access specific markets.

The intended use of the harvest should also be considered from the outset. A livestock farm producing forage or feed may choose a different crop combination from a farm targeting food markets or grain sales. Likewise, the intercrop should fit within the wider farming system and crop rotation, even though the most suitable approach will depend on local conditions and farm priorities.

Clear objectives make it easier to select suitable crop species, choose appropriate management strategies and harvesting options. They also provide a useful benchmark for evaluating whether the intercrop has been successful.

Rather than asking the general question “Which intercrop is best?”, it is more helpful to ask “Which intercrop is best suited to my objectives and farming conditions?”

This shift in perspective reflects one of the main lessons from the LEGUMINOSE project: successful intercropping depends on adapting the system to local circumstances rather than applying a universal recipe.



Choosing crop species

The success of an intercrop depends largely on how well the two crop species complement one another (see box “Why do some intercrops work better than others?” on page 14). Different species vary in how they acquire water and nutrients, compete for light and respond to environmental conditions. Selecting compatible crops is therefore one of the most important decisions when designing an intercrop.

Cereals and legumes often complement each other because they acquire nitrogen differently. Cereals rely entirely on nitrogen available in the soil. Legumes, in contrast, can obtain part of their nitrogen from the air through biological nitrogen fixation in association with soil bacteria. This reduces direct competition for soil nitrogen and allows both crops to make use of different nutrient sources.

However, this complementarity is not automatic. Nitrogen fixation is an energy-intensive process that also depends on access to other soil nutrients, including phosphorus, potassium and iron. Likewise, positive interactions are more likely when the two species differ in how they use resources, for example by exploring different soil layers, growing at different rates or responding differently to environmental conditions. When crops have very similar resource requirements, competition may outweigh the benefits (see box “Why do some intercrops work better than others?” on page 14). Therefore, choosing compatible species is one of the most important factors influencing success.

The benefits of intercropping are often greatest under low-input conditions, where nitrogen is more limiting. Under these conditions, legumes continue to fix atmospheric nitrogen while cereals make efficient use of soil nitrogen, reducing competition between the two crops. In contrast, high nitrogen fertiliser inputs tend to favour the cereal component, reducing biological nitrogen fixation and increasing the risk that cereals dominate the intercrop.

Common cereal partners include wheat, barley, oats, rye and triticale. These can be combined with legumes such as peas, faba beans, lupins, lentils or chickpeas. Each species has its own requirements and strengths, and the most suitable combination depends on local climate, soil conditions, available machinery and the intended use of the harvest.

Across the LEGUMINOSE Living Labs, farmers tested around 40 different cereal–legume combinations. Choices varied considerably between regions. Farmers in Mediterranean and drier environments frequently used chickpea and barley, while farmers in more temperate regions often selected combinations involving wheat, oats, peas or lupins. Fava beans proved particularly versatile and were used successfully across a wide range of environments and farming systems.

A successful intercrop is not necessarily the combination with the highest yield potential.

In practice, the best-performing systems are often those that balance productivity with stability, ease of management, efficient use of resources, reduced reliance on external inputs and suitability for the intended end use.

Designing and establishing a cereal–legume intercrop

Why do some intercrops work better than others?

The performance of an intercrop depends on the balance between competition and complementarity.

When two crops require the same resources at the same time, for example light, water or soil nutrients, they compete with one another. If one species grows much faster or becomes dominant, it may suppress the other and reduce the overall performance of the intercrop.

In contrast, complementarity occurs when crops use resources in different ways. One crop may obtain nitrogen from the atmosphere while the other relies on soil nitrogen. One species may develop deeper roots, while the other exploits nutrients closer to the soil surface. Differences in canopy structure or growth timing can also reduce competition and improve overall resource use.

When complementarity outweighs competition, the intercrop may produce more than would be expected from growing the two crops separately. This phenomenon

is known as over-yielding and is one of the main reasons why cereal–legume intercrops often outperform monocrops under suitable conditions.

Such plant interactions are often difficult to observe directly in the field, but they can sometimes be seen below ground. Root observation systems, known as root observatories or rhizotrons, can be used to study how root systems develop when different species grow together (Figure 1). In some intercrops, roots tend to avoid one another, reducing direct competition for resources. In others, roots grow towards each other, suggesting active communication through chemical signals in the rhizosphere. Such observations can help better understand how complementarity and competition, or interactions in general, influence intercrop performance.

The aim of successful intercrop design is therefore not simply to grow two crops together, but to select combinations that complement rather than compete with one another.

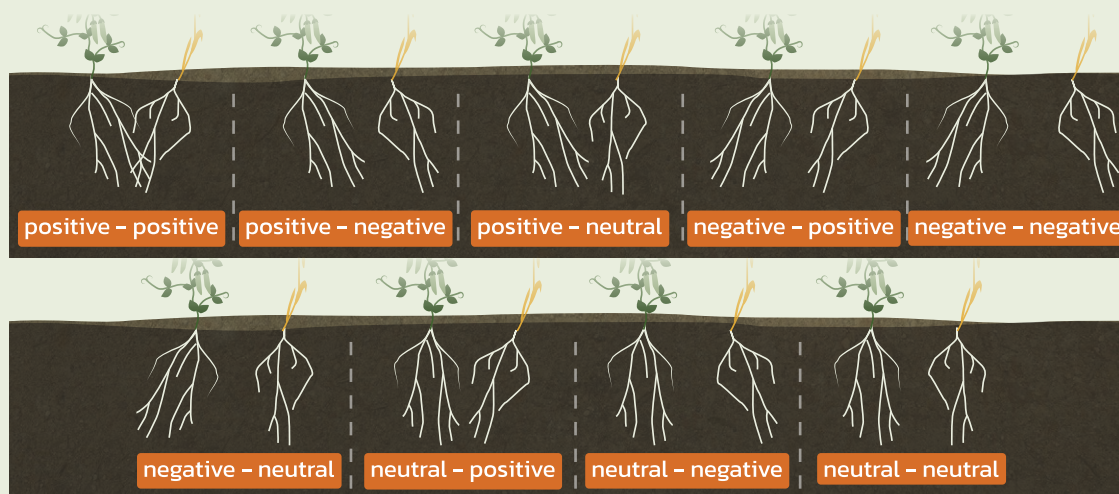
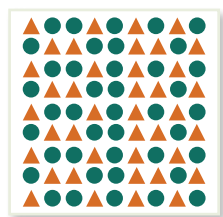


Figure 1: Root observations showing how different species may avoid one another or grow towards one another, providing insights into competition, complementarity and plant signalling.



Choosing an intercropping system

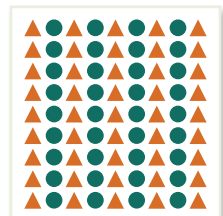
Once suitable crop species have been selected, the next decision is how they will be grown together. Cereal–legume intercroops can be established in different spatial arrangements, each with its own advantages and management requirements. The most appropriate system depends on available machinery, management preferences and the intended use of the harvest.



Mixed intercroops

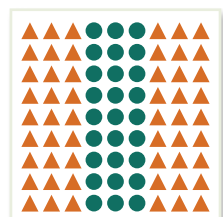
In mixed intercroops, cereal and legume seeds are sown together in the same rows. This is the simplest and most widely used approach. Around half of the LEGUMINOSE Living Lab farmers used mixed intercroops because they can often be established and harvested using standard farm machinery.

Mixed intercroops create the closest interaction between the two species and therefore offer the greatest opportunity for positive complementarity (see box “Why do some intercroops work better than others?” on page 14). However, they also require compromise. Both crops must usually be sown at the same depth and harvested together. Thus, not every crop combination is equally suitable for this intercropping system.



Row intercroops

In row intercroops, cereals and legumes are sown in alternating rows. This allows greater flexibility because sowing depth, fertilisation and other management decisions can be adjusted more precisely to the needs of each crop.



Strip intercroops

Strip intercroops extend the row–intercropping concept by growing multiple rows of cereals and legumes side by side.

This approach combines the benefits of species diversity with greater management flexibility. Crops can often be harvested separately, reducing the need for post-harvest separation and allowing different harvest dates when required.

A related approach is relay intercropping, where the second crop is sown later than the first crop. The two crops therefore share the field for only part of the growing season and are harvested at different times. Relay intercropping can help make more efficient use of the growing season while reducing competition between the crops.

Strip systems were particularly common in some of the warmer and drier regions participating in LEGUMINOSE (Spain, Pakistan, Egypt), where smaller harvesting equipment and flexible field operations made this approach attractive.

Designing and establishing a cereal–legume intercrop

Choosing the right system

There is no universally best intercropping system. Mixed intercrops generally maximise interactions between the crops and are straightforward to establish, whereas row and strip intercrops offer greater flexibility during crop management and harvest.

The most suitable choice depends on practical considerations such as machinery, harvesting strategy and the intended use of the crop.

Matching the intercropping system to the objectives of the farm is often more important than selecting the system that appears theoretically most productive.





Establishing the intercrop successfully

Successful intercropping depends not only on choosing suitable species but also on establishing both crops successfully. Small decisions made during sowing, from placement depth to plant density, can have long-lasting effects on crop development and final performance.

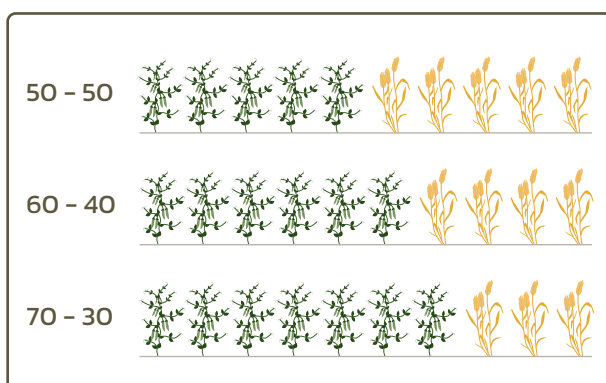
One of the main challenges is that cereals and legumes often have different agronomic requirements. Legume seeds are generally larger than cereal seeds and may require different sowing depths for optimal emergence. Growth rates and nutrient requirements can also differ between species. If one species emerges much faster than the other, it may become dominant and suppress its companion, reducing the overall benefits of the system.

Plant density and spatial arrangement also influence how strongly the two crops compete (Figure 2). How these densities are configured generally follows one of two design strategies:

- Replacement design: The seeding rates of both crops are proportionally reduced so that the combined total density equals that of a single standard monoculture. For example, 50% of the recommended cereal rate is combined with 50% of the recommended legume rate. This approach lowers inter-species competition and helps maintain a balanced share of resources between both crops.
- Additive design: The main crop is sown at its full standard seeding rate (100%), while the companion crop is added at a full or partial rate (e.g., an extra 30–50%). This increases total plant density on the field, which can maximize canopy cover and weed suppression. However, it also intensifies competitive pressure and therefore requires careful management to prevent one species from dominating.

Intercropping design based on seed density ratio

Replacement



Additive

More than 100, such as ...

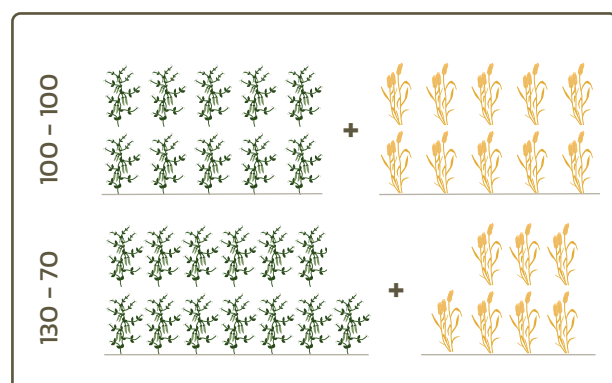


Figure 2: Two different seeding strategies for intercropping.

Designing and establishing a cereal–legume intercrop

Nutrient management, particularly nitrogen fertilisation, is another important consideration during establishment. Applying high rates of nitrogen at or before sowing frequently backfires: it stimulates rapid cereal growth, causing it to shade out the legume, while simultaneously inhibiting the legume's biological nitrogen fixation. Effective intercropping fertilisation often relies on reduced base nitrogen applications, split nitrogen applications, or prioritising starter phosphorus and potassium to encourage strong early legume root establishment without over-stimulating the cereal.

Experiences from the LEGUMINOSE Living Labs showed that establishment problems were responsible for many disappointing results. Poor seed placement, inappropriate sowing depth, incorrect seeding density and uneven emergence often had a greater impact on performance than the intercrop combination itself. Careful adjustment of drilling operations, machinery settings, spatial design, seeding rates and nutrient management can therefore make a substantial difference to final outcomes.

Planning for harvest from the beginning

Harvest planning should begin before sowing. Mixed intercrops generally require crop species with compatible maturity dates because both species are harvested together. Large differences in ripening can complicate harvesting and affect grain quality.

Row and strip intercrops offer greater flexibility because the crops can often be harvested separately. This may be advantageous when cereals and legumes mature at different times or when the harvest is intended for different markets.

The intended use of the harvest should also influence species selection and system design from the outset. Livestock farms may prioritise crop combinations

that can be used directly as feed or forage, reducing the need for grain separation. Farmers targeting food markets often need to consider quality requirements and post-harvest handling from the outset.

Food markets may also have strict requirements regarding grain purity, traceability and allergen management. These factors can make effective crop separation an important consideration when growing intercrops for human consumption.

Post-harvest handling, grain separation and marketing options are discussed further in the chapter "From harvest to market" on page 50.

Conclusion

Successful intercropping starts with careful planning. Species choice, intercropping system, establishment strategy and intended use of the harvest all influence performance and management requirements.

Experiences from the LEGUMINOSE Living Labs show that there is no universal recipe for success. Instead, the most effective systems are those that are adapted to local conditions, aligned with farm objectives and refined over time through practical experience.

For many farmers, the best approach is to begin on a small area, evaluate the results under local conditions and gradually adapt the system as experience grows.

Intercropping is therefore best viewed as a learning process, one that combines scientific knowledge with practical observation and continuous improvement.



LEGUMINOSE

Agronomic performance and resilience

Agronomic performance and resilience

Reliable crop production is becoming increasingly challenging as farmers face rising input costs, increasing weather variability and growing pressure to farm more sustainably. Yield remains a key measure of success, but it is no longer the only one. Farmers also need cropping systems that make efficient use of resources, remain productive under variable conditions and reduce production risks.

The LEGUMINOSE Living Labs and research field trials evaluated cereal–legume intercroops across a wide range of climates, soils and management systems. Together, these experiences provide robust evidence of how intercroops perform in practice and under which conditions they are most likely to deliver benefits.

Rather than asking whether intercroops always produce higher yields than monocrops, a more useful question is: Can they produce crops more efficiently and more reliably? The findings presented in this chapter suggest that, in many situations, the answer is yes.

Yield performance: do intercroops produce more?

The principle behind cereal–legume intercropping is that the two crops can complement one another in their use of light, water and nutrients. The results from LEGUMINOSE provide strong evidence that this can translate into higher productivity.

To assess this advantage and evaluate the agronomic performance of intercropping systems, researchers commonly use one of two indices: the Land Equivalent Ratio (LER) and the Net Effect Ratio (NER) (for more details, see box “Measuring agronomic performance” on page 22). Here, we use NER.

Across the 189 LEGUMINOSE Living Labs, 75% of all intercroops achieved positive net yield benefits (i.e. positive NER values) compared to sole crops (Figure 3). Only 25% showed yield depressions (NER < 1). On average, intercroops produced 31% more yield compared to monoculture systems (mean NER of 1.31), demonstrating a clear agronomic advantage of cereal–legume mixtures.

However, performance varied between crop combinations, locations and years. Some mixtures consistently delivered positive results across a wide range of environments, while others were more dependent on local conditions (Figure 4). For example, faba bean–based mixtures proved among the most reliable combinations across the Living Labs, while other combinations showed much greater variability between regions.

In some regions, particularly in Germany and the United Kingdom, the average NER effect was additive rather than positive. In other words, some crop combinations delivered clear benefits, while others showed little or no advantage, resulting in a neutral average overall. This highlights the importance of selecting crop combinations that have proven successful under local conditions, rather than assuming that all cereal–legume intercroops will perform equally well.

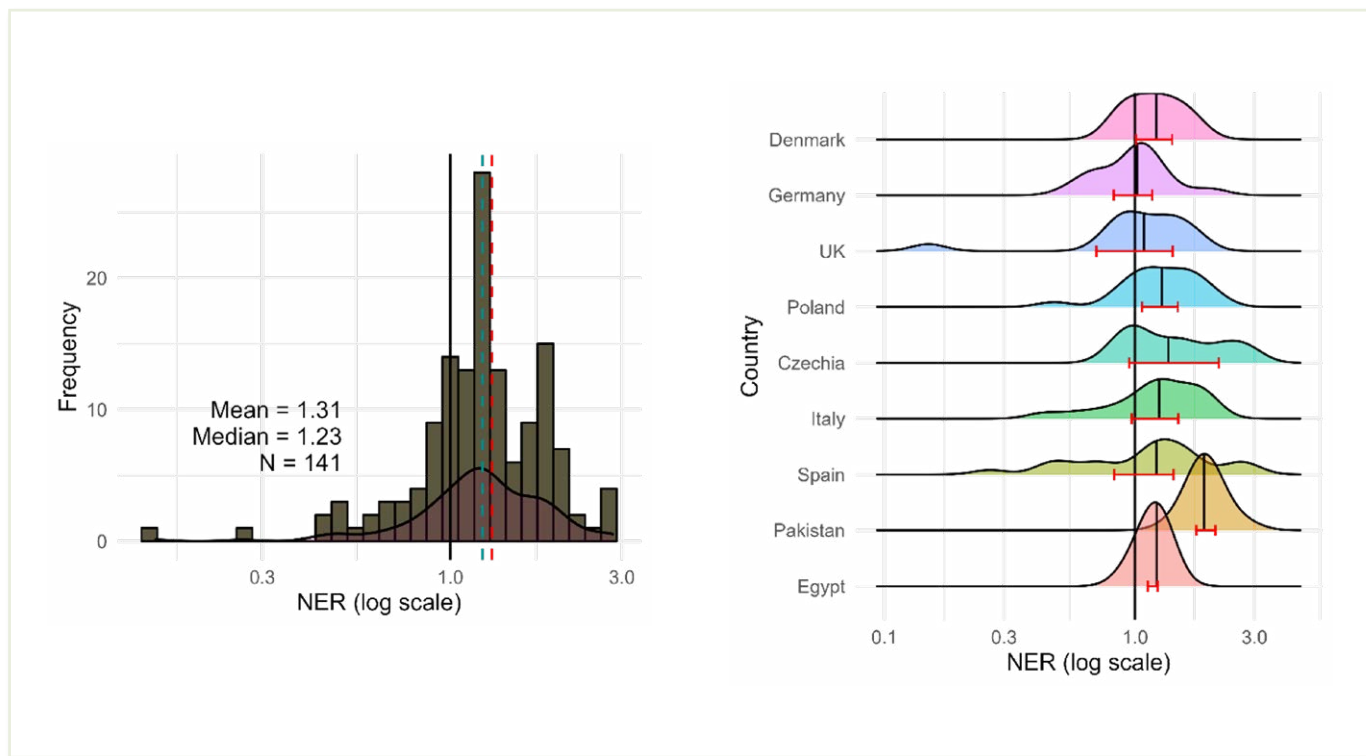


Figure 3: Net effects ratio from living lab on farm field trials

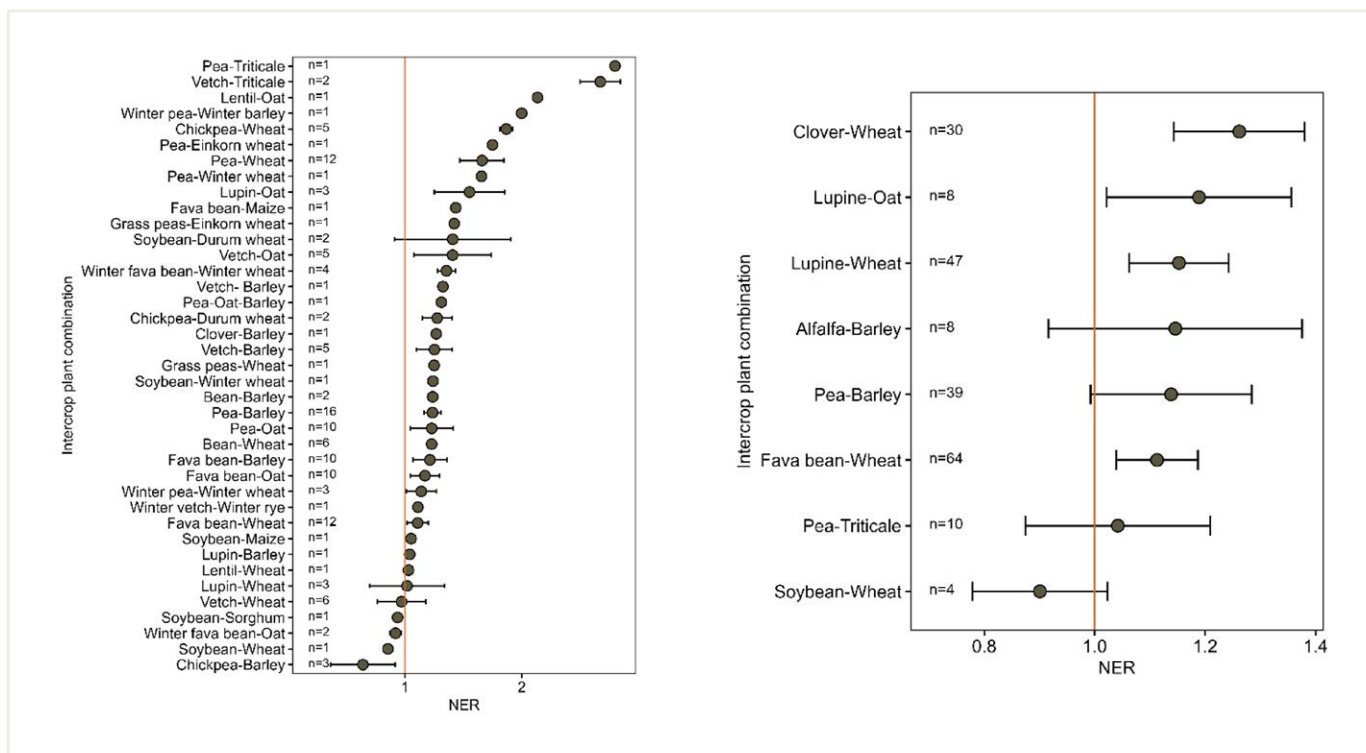


Figure 4: Ranking of the net effects ratio of individual intercrop combinations in on farm living labs (left) and research field trials (right).

Measuring agronomic performance

Comparing the performance of an intercrop with that of sole crops is not always straightforward. Cereals and legumes differ in their yield potential, growth patterns and contribution to the final harvest. Researchers therefore use different indicators to assess whether an intercrop provides a real agronomic advantage. Two of the most widely used are the **Land Equivalent Ratio (LER)** and the **Net Effect Ratio (NER)**.

The **Land Equivalent Ratio (LER)** compares the productivity of an intercrop with the productivity of the same crop grown separately as a monocrop. The LER is calculated as the sum of the relative yields of each crop in the intercrop compared with its respective sole crop.

- **LER > 1:** the intercrop uses land more efficiently than monocrops.
- **LER = 1:** no difference between systems.
- **LER < 1:** monocrops are more efficient.

For example, an LER of 1.25 means that 1.25 hectares of monocrop would be required to produce the same yield as 1 hectare of intercrop. In other words, the intercrop produces the same output using 20% less land.

The **Net Effect Ratio (NER)** compares the observed intercrop yield with the yield

expected from the proportions of each crop in the mixture.

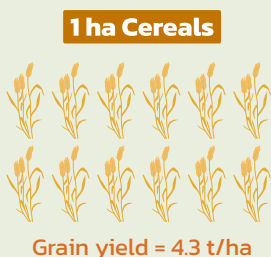
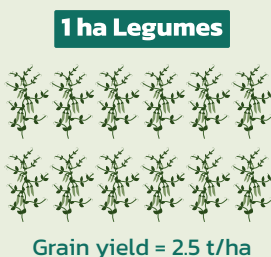
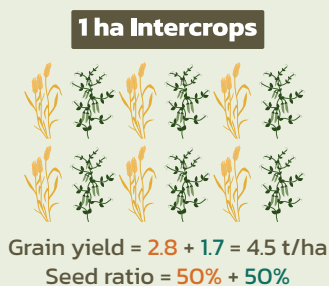
- **NER > 1:** positive intercrop advantage (over-yielding).
- **NER = 1:** performance matches expectations.
- **NER < 1:** yield depression.

For example, an NER of 1.32 indicates that the intercrop produced 32% more grain yield than expected from the corresponding monocrop grown on the same area.

Both indices provide slightly different perspectives on intercrop performance, but they are closely related and often lead to similar conclusions. While LER focuses on land-use efficiency, NER directly expresses the yield advantage (or disadvantage) of the intercrop relative to the yields of its component crops.

As a general rule for both indices:

- Values greater than 1 indicate an intercrop advantage (over-yielding).
- Values equal to 1 indicate no advantage or disadvantage.
- Values below 1 indicate yield depression compared with monocrop.



$$LER = \frac{2.8 \frac{t}{ha}}{4.3 \frac{t}{ha}} + \frac{1.7 \frac{t}{ha}}{2.5 \frac{t}{ha}} = 1.25$$

$$NER = \frac{4.5 \frac{t}{ha}}{0.5 * 4.3 \frac{t}{ha} + 0.5 * 2.5 \frac{t}{ha}} = 1.3$$



Yield stability and risk reduction

For many farmers, yield stability is just as important as maximum yield. A slightly lower but reliable harvest may be preferable to a system that performs exceptionally well in favourable years but poorly under stress.

One of the major strengths of intercropping is its ability to spread risk across two crop species. Cereals and legumes respond differently to weather conditions, pests, diseases and nutrient availability. When one crop performs poorly, the companion crop can often compensate.

This buffering effect became particularly evident in the LEGUMINOSE Living Labs and research field trials during the 2024 growing season. Prolonged periods of rainfall in parts of Germany and the Czech Republic caused severe fungal disease outbreaks in field peas, leading to near-total losses of field peas. The cereal component in the intercropped fields, however, remained largely unaffected and helped maintain overall productivity.

The research field trials confirmed this buffering effect. On average, intercrops reduced yield variability, measured using the coefficient of variation (CV), by around 10% compared with sole crops (Figure 5). For more details on how to calculate CV, see box “Measuring yield stability” on page 24. The strongest improvements in stability were observed for peas, fava beans and lupins grown in mixtures.

The Living Labs also revealed differences in crop failure rates. Approximately 20% of legume trials failed before harvest, compared with around 10% of cereal trials. This indicates a higher sensitivity of legumes towards environmental perturbations. Intercrops, on the other hand, performed better, with failure rates of around 15%, and most failures were linked to establishment problems rather than pest or disease damage.

Taken together, these findings indicate that intercropping can reduce production risk by making the overall system less dependent on the success of a single crop. While one component may occasionally perform poorly, the second crop often helps maintain overall productivity.

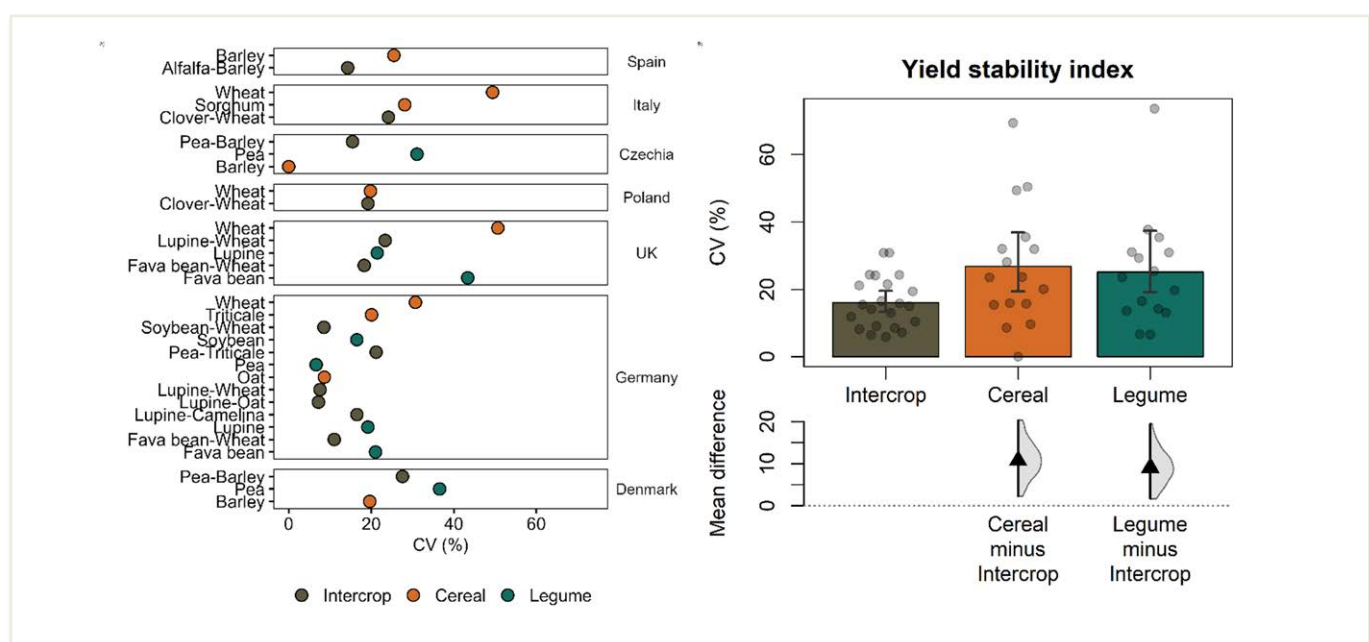


Figure 5: Yield stability expressed as coefficient of variation (lower CV = more stable yield).

Agronomic performance and resilience

Measuring yield stability

Yield stability describes how consistently a cropping system performs across different years or growing conditions. Yield stability is commonly assessed using the **Coefficient of Variation (CV)**.

- Low CV: yields are relatively stable.
- High CV: yields are more variable.

A lower CV indicates that yields fluctuate less between years or locations and therefore carry lower production risk.

The formula for calculating the CV is:

$$CV(\%) = \frac{\sigma}{\mu} \times 100$$

where σ is the standard deviation of yield, and μ is the mean yield.

Climate and weather resilience

Climate change is increasing the frequency of droughts, heat stress and other weather-related challenges. Cropping systems that maintain productivity under such conditions are therefore becoming increasingly important.

Results from the Living Labs suggest that intercropping may provide its greatest advantages under challenging growing conditions. Yield benefits increased with higher temperatures and lower annual precipitation, indicating that intercrops often perform particularly well in warmer and drier environments.

Our data also showed stronger intercrop advantages on soils with lower nitrogen availability. Where nitrogen was limited, cereals and legumes complemented one another more effectively, whereas the advantage

declined as nitrogen availability increased. This highlights that intercropping is particularly effective in lower-input systems where nutrients are more limiting.

Positive effects were also observed on alkaline soils where some legumes typically struggle. This indicates that intercropping can help compensate for environmental constraints and maintain productivity under less favourable conditions, e.g. on soils with low fertility and reduced nutrient availability.

Taken together, these findings suggest that intercropping can serve as a practical adaptation strategy for farmers facing increasingly variable climatic conditions.



Resource-use efficiency and crop quality

Many of the productivity advantages of intercropping arise from the complementary way cereals and legumes use resources.

Evidence for this improved resource-use efficiency can be seen not only in crop yields but also in grain quality. Across the LEGUMINOSE Living Labs and research trials, cereals grown in intercrops consistently contained between 1.9 and 3.4 percentage points more protein than cereals grown alone, with an average increase of 2.4 percentage points (Figure 6). This effect was observed across wheat, barley, oats and triticale. In contrast, protein concentrations in legumes showed little difference between sole crops and intercrops.

Because nitrogen fertiliser applications were adjusted according to cereal seeding rates, these results suggest that intercrops were able to use available nitrogen more efficiently than monocropping systems.

Field experiments also revealed increases in several micronutrients, including iron, phosphorus, magnesium and calcium, in intercropped barley compared with sole-cropped barley (Figure 7). Although these findings require further validation across a wider range of crop combinations and environments, they highlight the potential of intercropping to improve nutritional quality as well as productivity.

Higher cereal protein concentrations can increase the value of the harvest for both food and feed markets. For food production, higher protein content can improve processing characteristics, such as bread-making quality in wheat. For livestock production, higher protein concentrations increase the nutritional value of the grain and may reduce the need to supplement feed with additional protein sources. The economic implications of these quality improvements are discussed further in the chapter "From harvest to market" on page 50.

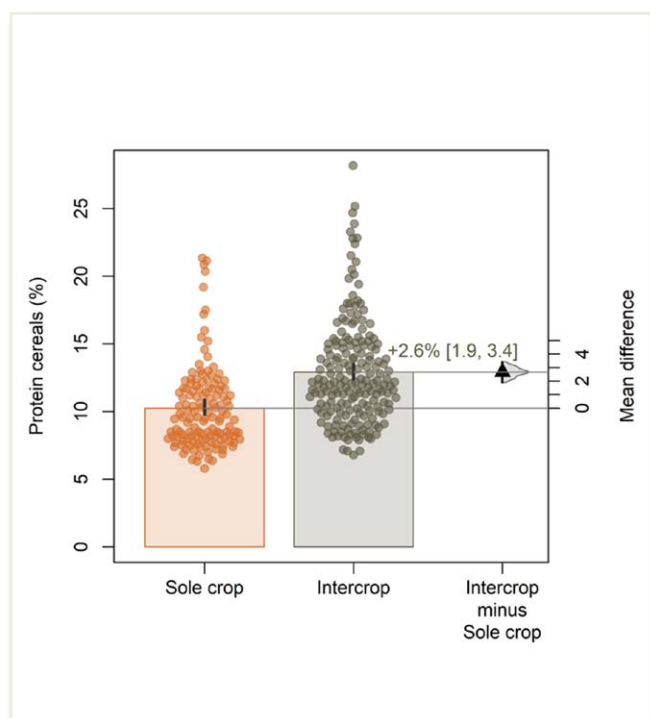


Figure 6: Protein content in cereals from research field trials / Protein content in cereals grown as sole crops and intercrops in LEGUMINOSE research trials.

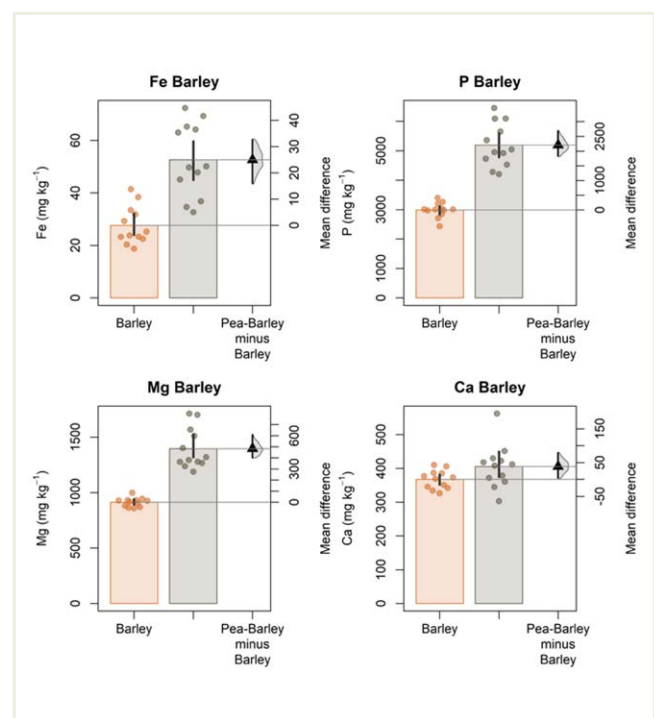


Figure 7: Macronutrient content in barley from Danish field experiments.

Which crop combinations performed best?

Not all intercrops perform equally well. Species choice remains one of the most important factors determining success.

Across both Living Labs and research trials, several crop combinations consistently delivered positive results across different environments (Figure 4 on page 21):

- lupin–oat
- pea–oat
- pea–barley
- clover–wheat
- fava bean mixtures

Fava bean combinations were particularly notable for their consistency across sites and their contribution to yield stability.

Other combinations performed less reliably. Chickpea–barley, soybean–wheat and winter fava bean–oat mixtures often showed weaker results. Soybean generally proved less suited to intercropping than many of the other legumes tested. This does not necessarily mean these combinations are unsuitable, but rather that their success appears to depend more strongly on local environmental conditions and management.

Overall, these findings reinforce an important lesson from the LEGUMINOSE project: species choice matters. Selecting crop combinations that are well adapted to local conditions is one of the most effective ways to improve intercrop performance.

Conclusion

Across the LEGUMINOSE Living Labs and research field trials, cereal–legume intercrops frequently improved productivity, stability and crop quality compared to monocrops. The greatest advantages were often observed under warmer, drier and low-input conditions, suggesting that intercropping can play an important role in adapting agriculture to future environmental challenges.

The results also highlight that successful intercropping is not determined by a single factor. Crop choice, management and local growing conditions all influence performance. Selecting compatible crop combinations and adapting them to local conditions are therefore key to realising the benefits of intercropping.



LEGUMINOSE

Soil health and environmental benefits

Soil health and environmental benefits

The benefits of cereal–legume intercropping extend beyond crop yields and farm productivity. By combining species with different growth habits, rooting patterns and nutrient requirements, intercrops can influence soil processes, nutrient cycling, biodiversity and environmental performance in ways that support the long-term sustainability of farming systems.

Many of these benefits develop gradually and may not be immediately visible within a single growing season. Nevertheless, they can contribute to healthier soils, more efficient resource use and reduced environmental impacts over time.

Soil health and soil biology

Healthy soils are living ecosystems. Alongside plant roots, they contain vast communities of bacteria, fungi, earthworms and other organisms that help regulate nutrient cycling, organic matter decomposition and soil structure.

One of the questions investigated within the LEGUMINOSE project was how cereal–legume mixtures influence biological processes in the rhizosphere, the narrow zone of soil surrounding plant roots where plants and soil microorganisms interact most intensely. The rhizosphere is often described as the root–soil interface because it is where nutrients, roots and soil organisms come together and influence one another.

To explore these interactions, we analysed functional genes of soil microorganisms.

These genes contain the instructions for producing enzymes that drive key soil processes. By examining them, we can assess the capacity of soil microbial communities to perform functions such as nutrient

transformation and mineralisation, organic matter decomposition and the regulation of greenhouse gas emissions. In particular, the project focused on microbial functions involved in the nitrogen cycle, one of the most important processes governing soil fertility and plant nutrition.

Legumes were particularly effective at stimulating soil microorganisms involved in nitrogen cycling. Intercropped cereals benefited from these processes through their efficient uptake of available nitrogen.

This created a more active and efficient nitrogen cycle in the root zone than was typically observed in sole crops. The findings suggest that some of the advantages of intercropping arise not only from the crops themselves but also from the interactions between plant roots and soil microorganisms.



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Another important finding was that intercropping optimised the final stages of the nitrogen cycle. Our analyses indicated that intercrops supported microbial communities with a greater capacity to convert nitrous oxide (N_2O), a potent greenhouse gas, into harmless atmospheric nitrogen (N_2). This suggests that intercropping can improve nutrient cycling while reducing some of the environmental risks associated with surplus nitrogen.

Overall, our results suggest that cereal–legume intercrops create a more tightly coupled and efficient nitrogen cycle in the root–soil interface (Figure 8). By combining crop species with complementary nutrient-acquisition strategies, intercrops stimulate soil biological processes that help recycle nitrogen more effectively. In this sense, the benefits of intercropping are created not only by the crops themselves but also by the biological communities that develop around their roots.

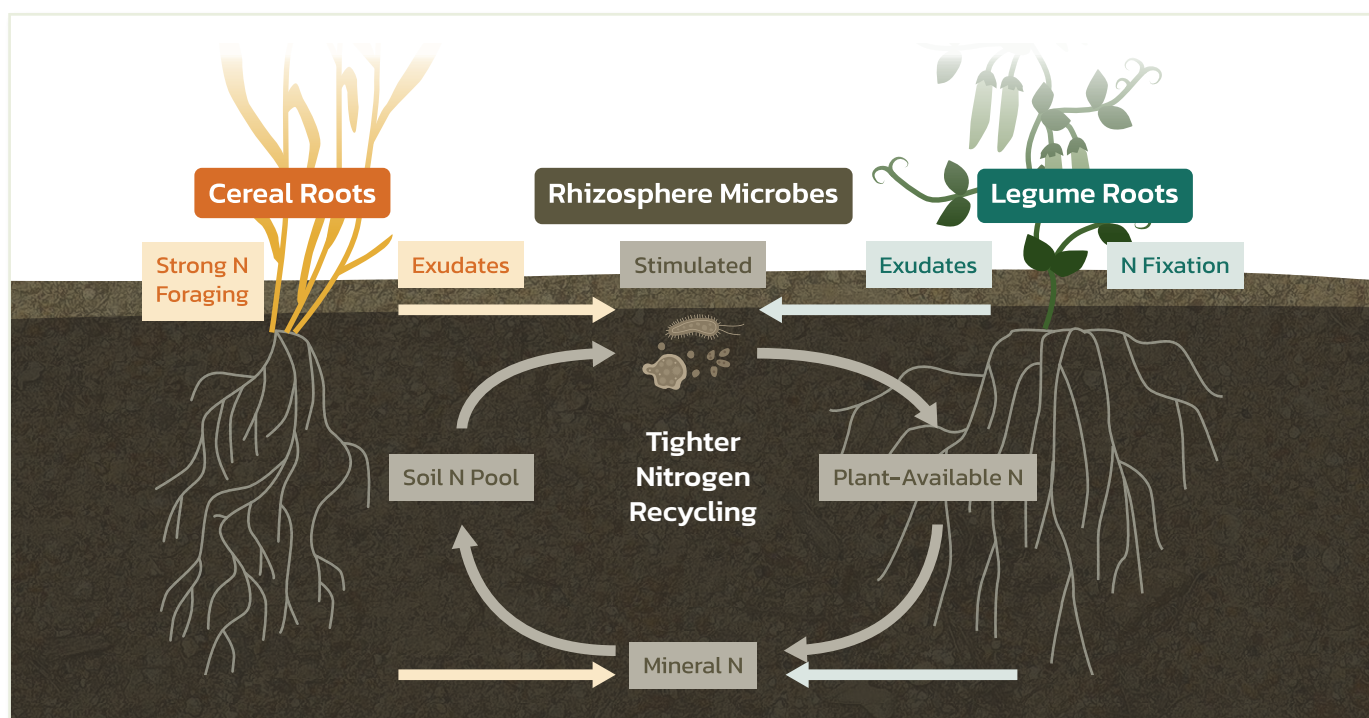


Figure 8: Cereal–legume intercropping promotes efficient nitrogen recycling.

Water and nutrient cycling

One of the key advantages of combining cereals and legumes is the complementary way they use resources. Cereals obtain nitrogen primarily from the soil, whereas legumes can obtain part of their nitrogen through biological nitrogen fixation. This reduces direct competition for nitrogen and allows the two crops to exploit different nutrient sources.

These interactions can influence nutrient dynamics long after harvest. Legume crops are often less efficient at capturing all available soil nitrogen and can leave

substantial amounts of residual nitrogen in the soil. While this residual nitrogen can benefit subsequent crops by reducing their fertiliser needs, it can also increase the risk of nitrate leaching and nitrous oxide emissions if it is not taken up by plants.

Previous studies indicate that cereal–legume intercropping can reduce nitrate-leaching risks by approximately 10–16% compared with sole legume crops (for a comprehensive review, see *Jensen et al., 2020*). Results from the LEGUMINOSE field experiments

Soil health and environmental benefits

illustrated this effect clearly. In a German winter wheat–fava bean experiment, sole-cropped faba beans left between 83 and 116 kg mineral nitrogen per hectare in the soil after harvest. When faba beans were grown together with wheat, residual mineral nitrogen levels were reduced by approximately 28–32% (Figure 9). This means that more nitrogen was captured and used by the crop, reducing the amount remaining in the soil and lowering the risk of environmental losses.

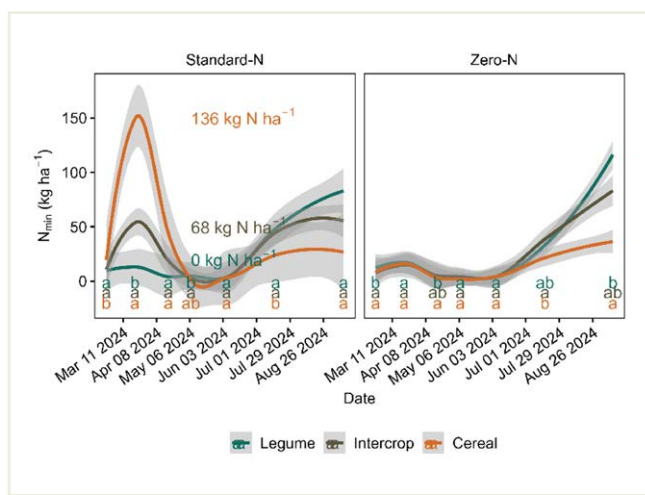


Figure 9: Mineral nitrogen stocks (N_{min}) in 0–30 cm soil depth from Fava-bean – Winter wheat research trials in Germany. The trials included standard N fertilisation and zero N fertilisation.

These effects also have implications for greenhouse-gas emissions. A key finding from the LEGUMINOSE project was that the greenhouse-gas potential of 50:50 cereal–legume intercrops, expressed as carbon dioxide equivalents (CO_2e), was consistently intermediate between the corresponding cereal and legume monocultures. Intercropping reduced the potential for nitrous oxide emissions through several interacting mechanisms: lower residual nitrogen levels after harvest, more balanced carbon-to-nitrogen ratios in crop residues, and reduced dependence on nitrogen fertiliser inputs. Together, these factors contributed to lower greenhouse-gas emission potential while maintaining productive cropping systems.

Biological nitrogen fixation by legumes is an energy-intensive process that is highly sensitive to water availability. Water shortages during flowering and pod

filling can reduce nitrogen fixation and increase the risk of flower or pod shedding in legumes. Efficient water use is therefore particularly important in cereal–legume systems, as maintaining adequate water supply helps sustain both nitrogen fixation and crop productivity.

One way intercrops achieve this is through complementary rooting patterns. Different crop species often access different soil layers, allowing them to access water from different depths and reducing direct competition for the same resources. For example, the root system of faba bean is shallower (0.6–0.8 m) compared to that of wheat (>1.8 m). As a result, we observed that the two crops accessed water from different depths and competed less directly for the same resources (Figure 10). This complementarity becomes particularly important under drought conditions. By accessing water from different soil layers, intercrops may maintain productivity more effectively than sole crops when water availability becomes limiting.

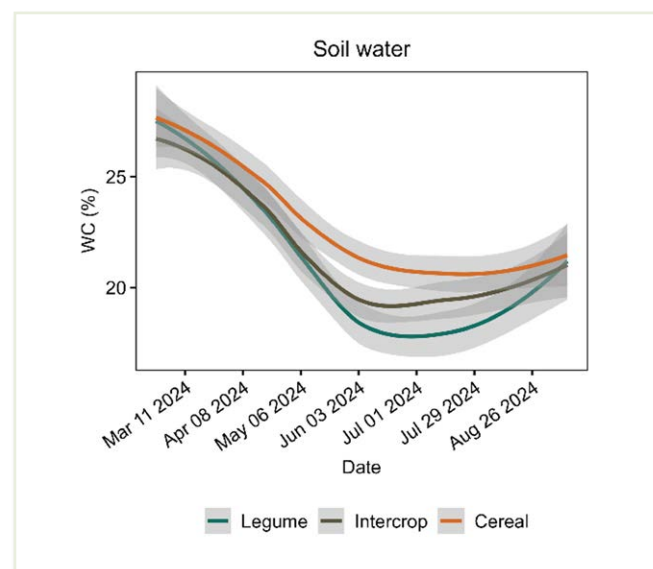


Figure 10: Soil water content from Fava-bean – Winter wheat research trials in Germany.

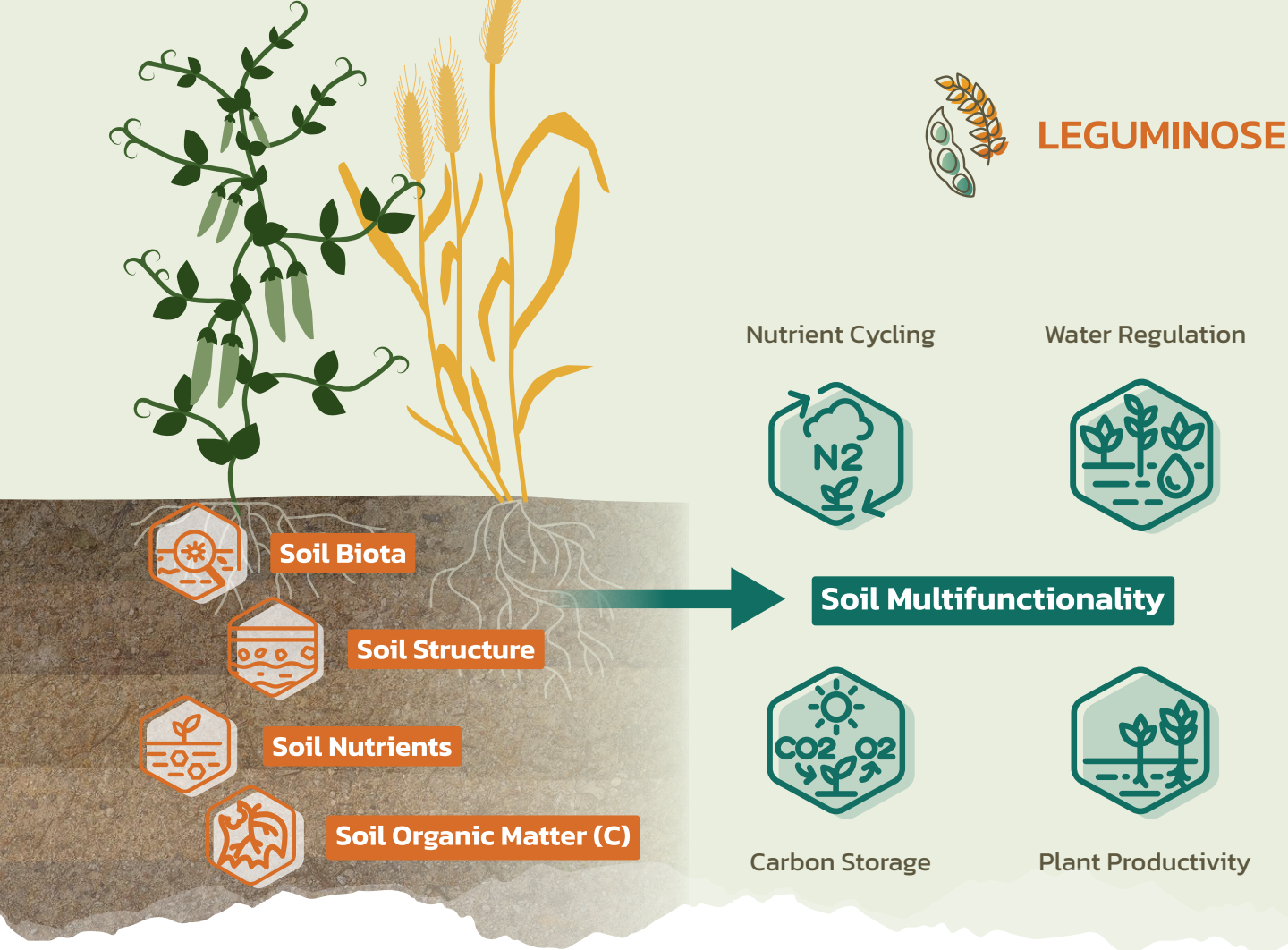


Figure 11: The concept of multifunctionality.

Soil multifunctionality and environmental sustainability

Agricultural soils are expected to perform many functions simultaneously. They must support crop production, cycle nutrients, regulate water, sustain biodiversity and minimise environmental losses. The ability of a soil to provide several of these functions at the same time is often referred to as soil multifunctionality (Figure 11). Soil multifunctionality is a central indicator in the concept of soil health.

To evaluate soil multifunctionality in intercropping systems, we combined 20 indicators of physical, chemical and biological soil properties into a multifunctionality index. We calculated a multifunctionality index based on data from three research field trials. The results showed that cereal–legume intercroops consistently increased soil multifunctionality compared with sole crops, particularly under low-input conditions where nutrient availability was limited (Figure 12). The positive effects became less pronounced when large amounts of fertiliser or manure were applied, suggesting that the

ecological benefits of plant diversity are most visible when resources are scarce.

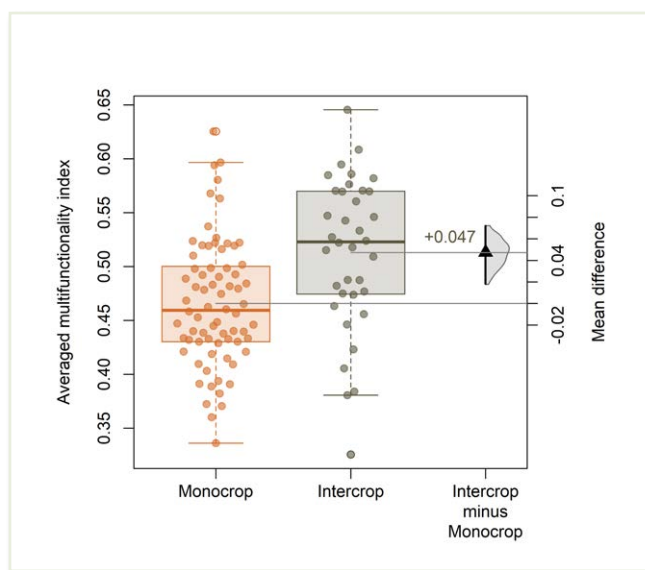


Figure 12: Measured multifunctionality index from 25 soil parameters. The results are summarized from 3 different research field trials

Conclusion

The LEGUMINOSE results show that cereal–legume intercrops influence much more than crop production. By improving nutrient cycling, supporting biologically active soils, reducing residual nitrogen and making more efficient use of water, they can enhance several key soil functions simultaneously.

Many of these effects develop gradually and may not be immediately visible within a single growing season. Over time, however, they can contribute to healthier soils, greater resource–use efficiency and more environmentally sustainable cropping systems.





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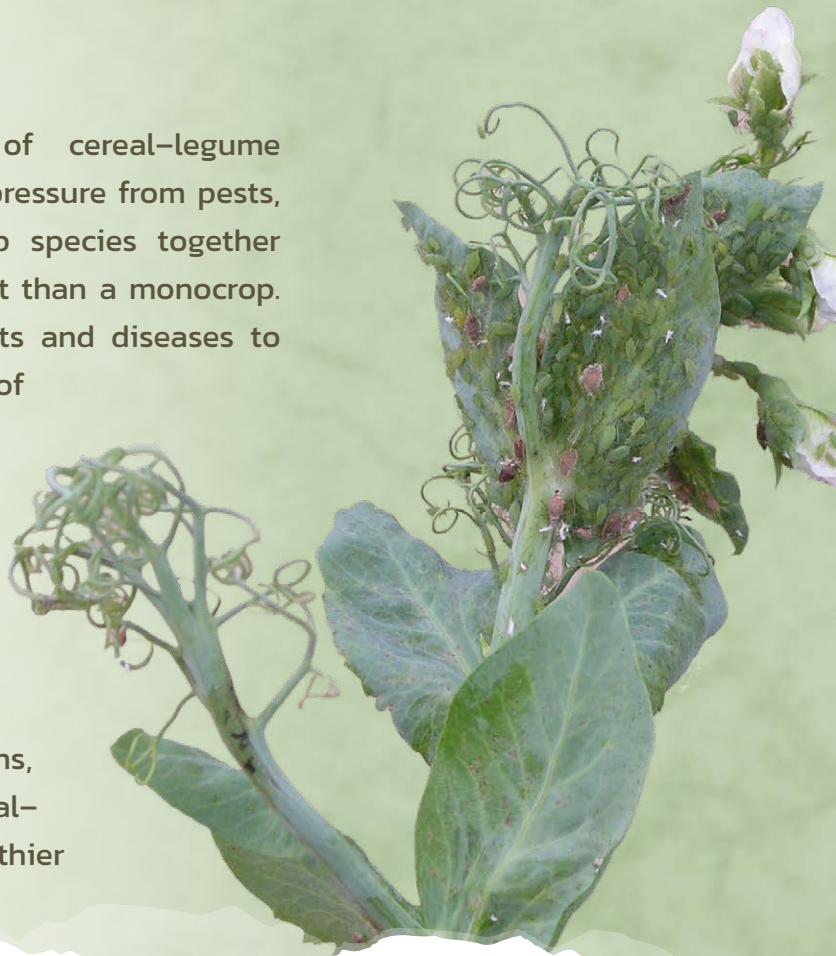


Pest, disease and weed regulation

Pest, disease and weed regulation

One of the practical advantages of cereal–legume intercropping is its potential to reduce pressure from pests, diseases and weeds. Growing two crop species together creates a more diverse field environment than a monocrop. This can make it more difficult for pests and diseases to spread and may improve the activity of beneficial organisms.

Results from LEGUMINOSE Living Labs and research field trials show that intercropping can contribute to biological crop protection in several ways. While the effects vary between crop combinations, locations and seasons, the overall evidence suggests that cereal–legume intercrops can contribute to healthier and more resilient cropping systems.



Pea aphids colonies (*Acyrthosiphon pisum*)

Pest suppression

Several LEGUMINOSE trials found lower levels of damage from crop pests in cereal–legume intercrops compared to monocrops.

In cereal crops, damage caused by the cereal weevil was often lower when cereals were grown together with legumes (Figure 13). These insects feed on the upper leaves, reducing the crop's ability to intercept sunlight and ultimately affecting grain production. Across several trials, cereals grown in intercrops generally experienced less damage than cereals grown alone.

Similar effects were observed in legume crops. Pea aphids, one of

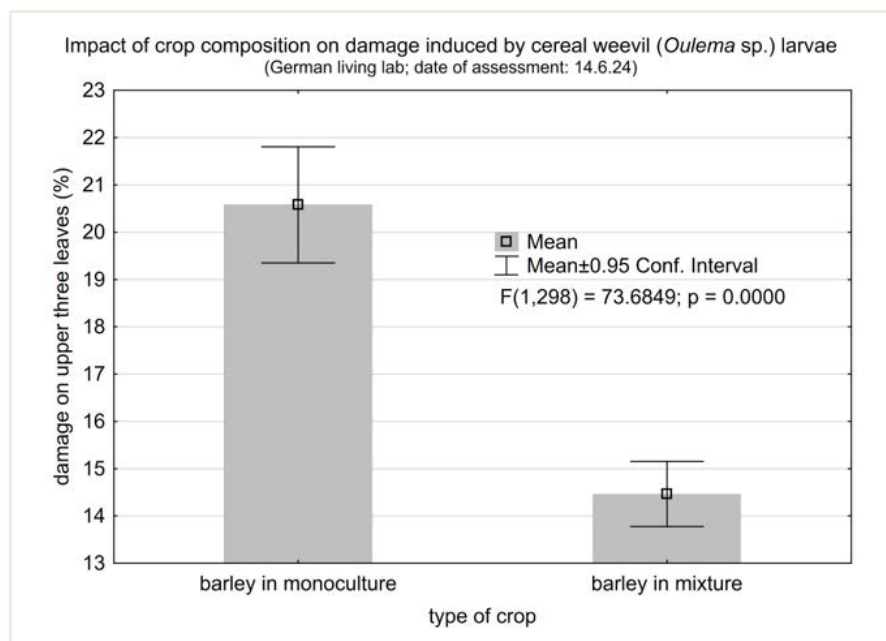


Figure 13: Reduced damage caused by cereal weevil (*Oulema* sp.) on intercropped barley in one of the German living labs.



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the most important insect pests of field pea, were frequently less abundant in pea-cereal intercrops than in pea monocrops (Figure 14). This is particularly important because aphids not only feed directly on plants but can also transmit viruses that reduce both yield and grain quality.

Damage caused by pea leaf weevils was also often reduced in intercrops (Figure 15). These insects are especially harmful because their larvae feed on the nitrogen-fixing nodules on legume roots, reducing the plant's ability to obtain nitrogen naturally.

The exact reasons behind these effects differ between pests and cropping systems and are not yet fully understood. In many cases, however, the presence of a companion crop appears to make it more difficult for specialist pests to locate and exploit their preferred host plants.



Pea leaf weevil
(*Sitona* sp.)

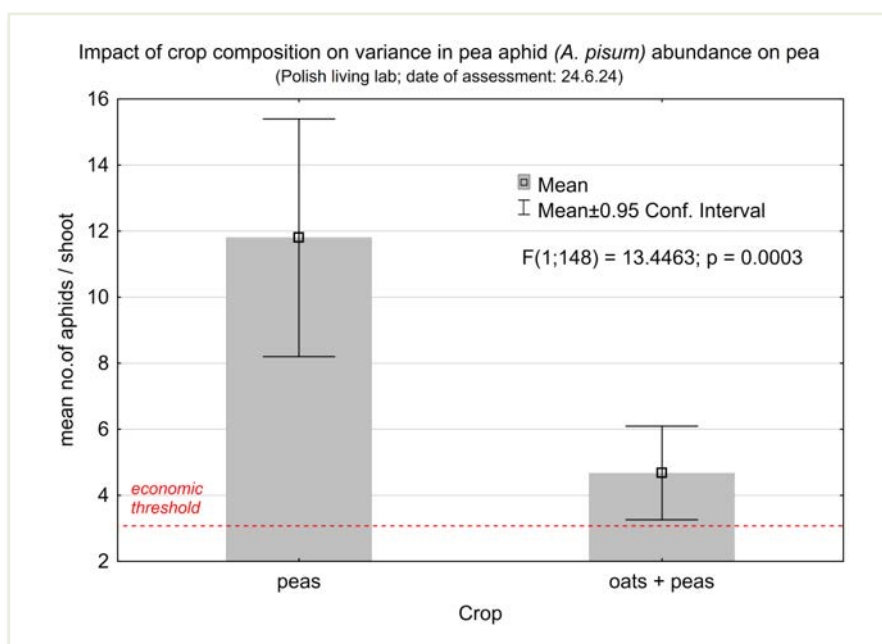


Figure 14: Reduced aphid abundance on field pea intercropped with oats in one of the Polish living labs.

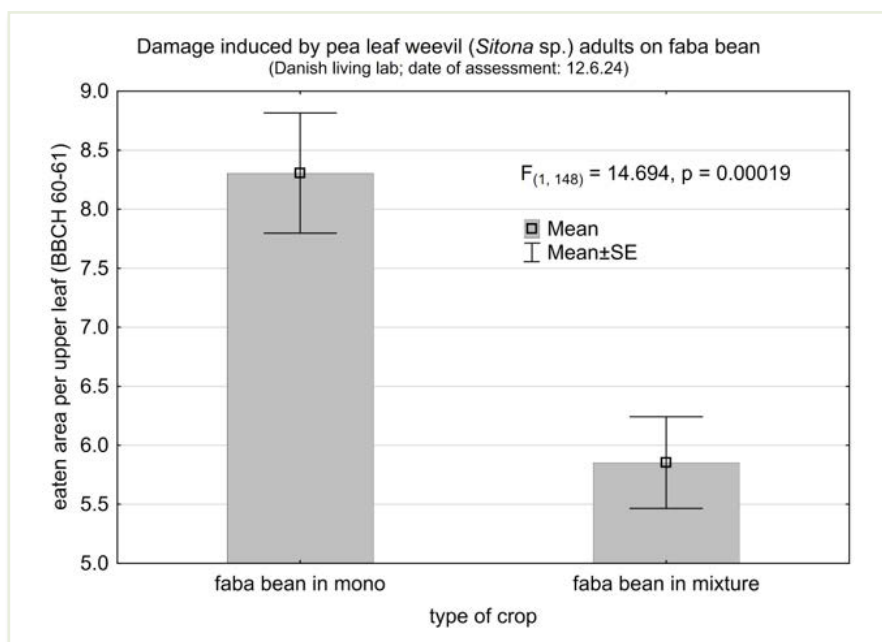


Figure 15: Reduced damage caused by pea leaf weevil (*Sitona* sp.) on intercropped faba beans in one of the Danish living labs.

Beneficial insects and natural enemies

Intercropping can do more than reduce pest pressure directly. It can also create a more favourable habitat for beneficial insects that naturally regulate pest populations.

Across several LEGUMINOSE trials, aphid populations in intercrops were exposed to stronger pressure from predators and parasitoids than in monocrops (Figure 16).

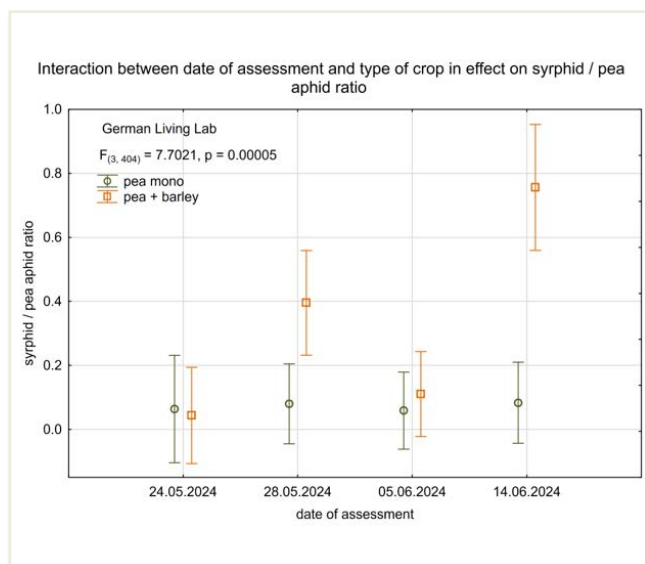


Figure 16: Temporal change in syrphid / pea aphid ratios in the pea monocrop and the pea-barley intercrop on four consecutive dates of assessment in one of the German Living labs. Note: aphidophagous syrphids are crucial predators of pea aphids.

Beneficial insects such as hoverflies, lacewings and parasitic wasps were often more abundant or more active in intercrops, contributing to a faster decline in aphid populations (Figure 17).

We also observed greater diversity of some beneficial insect groups in intercrops than in monocrops. A greater diversity of natural enemies can improve the stability of biological pest control and reduce the likelihood of pest outbreaks.

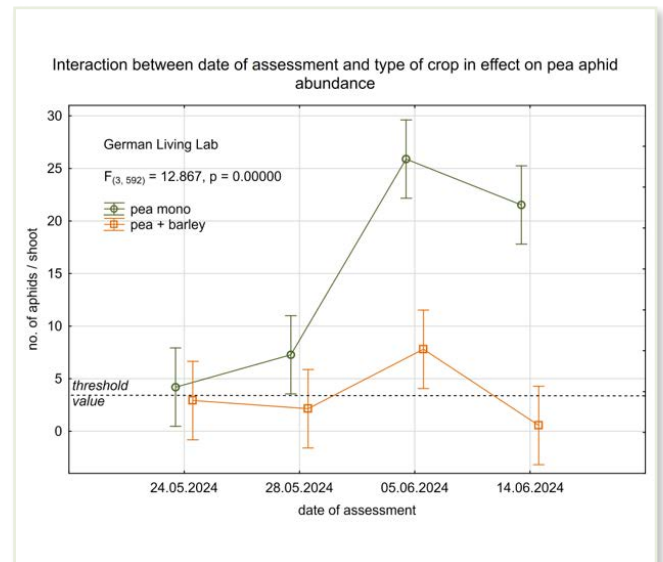


Figure 17: Temporal change in pea aphid abundance in the pea monocrop and the pea-barley intercrop on four consecutive dates of assessment in one of the German living labs.

These findings highlight an important advantage of crop diversity: by creating a more varied habitat, intercrops can support the ecological processes that help keep pest populations under control.



Disease regulation

Intercropping can also reduce the spread of some crop diseases.

The clearest results from LEGUMINOSE were observed for cereal rust diseases. In several trials where rust pressure was high, cereals grown in intercrops showed lower disease incidence and severity than cereals grown in monoculture (Figure 18). This suppressive effect was observed across different cereal species and intercrop combinations.

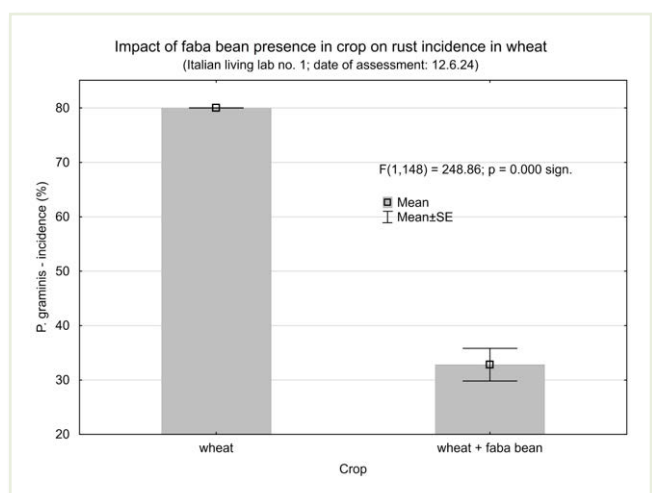


Figure 18: Reduced rust incidence in cereal-legume intercrops. Rust occurrence in one of Italian living labs.

For other diseases, the picture was less consistent. Some leaf spot and blotch diseases showed weaker or more variable responses to intercropping. This suggests that disease suppression depends on the specific pathogen, crop combination and local growing conditions.

Overall, our results indicate that intercropping can be an effective component of integrated disease management, particularly for diseases that spread easily within dense stands of a single crop species.



Pest, disease and weed regulation

Weed suppression

Weed management is often a challenge in legume crops because many legume species are relatively poor competitors against weeds, especially during the early stages of growth.

Adding a cereal companion crop can substantially improve weed suppression. In many LEGUMINOSE trials, cereal–legume intercrops reduced weed pressure compared with legume monocrops. The cereal component usually establishes more rapidly, capturing

light, water and nutrients before weeds become established.

This stronger crop competition can reduce weed growth and contribute to more stable crop performance, particularly in organic and low-input farming systems where herbicide options are limited. Although weed control should not be the sole reason for adopting intercropping, it can be an important additional benefit that reduces reliance on other weed-management measures.



Conclusion

Results from the LEGUMINOSE Living Labs and research trials indicate that cereal–legume intercropping can strengthen the natural regulation of pests, diseases and weeds.

The most consistent findings were lower aphid abundance, reduced damage from cereal weevils and pea leaf weevils, slower development of cereal rust diseases, increased activity of beneficial insects and improved weed suppression in legume crops.

Although outcomes vary between locations, crop combinations and growing seasons, the overall evidence suggests that intercropping can enhance the ecological processes that support resilient and sustainable crop production.



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Category	Main effect observed in intercrop
Cereal leaf weevil (Oulema sp.)	Lower crop damage induced by larvae
Sitona leaf weevil (Sitona sp.)	Lower crop damage, but not in all cases, depends on crop composition
Seed weevils (Bruchus pisorum and B. rufimanus) [MB1.1]	Low direct impact of intercropping on these insect pests
Pea aphid (Acyrthosiphon pisum)	Lower abundance, faster decline of aphid colonies
Black bean aphid (Aphis fabae)	Low direct impact of intercropping on this aphid
Cereal aphids (S. avenae, R. padi, M. dirhodum)	Lower abundance, faster decline of aphid colonies
Natural enemies of pea aphids	Higher abundance, especially in the case of aphidophagous syrphids and hymenopteran parasitoids from subfamily Aphidiinae
Natural enemies of black bean aphids	Likely low impact of intercropping
Natural enemies of cereal aphids	Higher abundance, especially in the case of hymenopteran parasitoids from subfamily Aphidiinae
Natural enemies of seed weevils (B. pisorum and B. rufimanus)	Higher levels of bruchid larvae parasitisation induced by braconid Triaspis thoracicus
Ascochyta blight on field pea and faba bean	No strong suppressive effect of intercropping on the causal agents of this field pea disease
Cereal rusts in general	Lower incidence and severity, strong suppressive impact of intercropping
Leaf spots and blotches on wheat, barley, and oat	No strong suppressive impact of intercropping on the pathogens causing these diseases (Pyrenophora teres, P. graminea, P. avenae, P. tritici-repentis, Zymoseptoria tritici, Stagonospora nodorum, Rhynchosporium secalis, Cochliobolus sativus)
Dicotyledon (broad leaf) weeds in general	Lower abundance and density

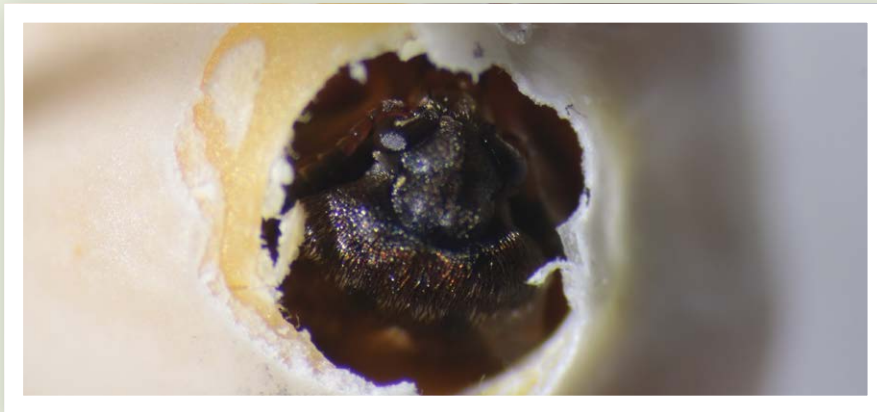
Pest, disease and weed regulation



Seed pea weevil, *Bruchus pisorum*



Females of *B. pisorum* lay characteristic, well visible, orange eggs on green pods.



Larvae of *B. pisorum* pupate inside pea seeds. The whole larval development of *B. pisorum* takes place inside the field pea seeds. At the end, newly hatched adults leave the seeds.

It is very difficult to control the pest with available insecticides.

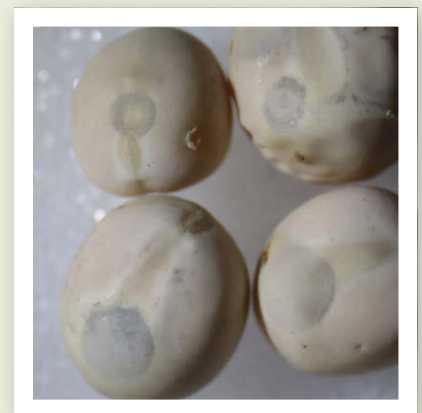
Some portion of *B. pisorum* larvae can be parasitised by hymenopteran wasps. It is easy to distinguish infested seeds in which the development of *B. pisorum* was successful (lower two seeds) from the ones where the larvae were attacked by their parasitoids (the upper ones) according to the diameter of openings.



The most frequent parasitoid of *B. pisorum* is the braconid wasp *Triaspis thoracica*.



Pteromalid wasps from the genus *Eupteromalus* are less frequent.



The levels of *B. pisorum* larvae parasitisation were higher in cereal/field pea intercrops than field pea monocrops.



LEGUMINOSE

Economics and farm performance

Economics and farm performance

When considering cereal–legume intercropping, yield is often the first question farmers ask. However, yield alone does not determine whether an intercrop is economically successful.

Across the systems studied in LEGUMINOSE, economic performance depended not only on how much was harvested, but also on how the harvest was used, what inputs were required, and what costs were incurred after harvest. In some cases, intercrops produced lower yields than cereal monocrops. In others, the combined output of the cereal and legume matched or exceeded that of the reference crops.

For this reason, the most important question is not simply “How much did the crop yield?” but rather “What value does this crop create for my farm?” The answer depends on factors such as feed savings, fertiliser savings, market opportunities, processing requirements and the role of the crop within the wider farming system.

Looking beyond yield

Intercropping may create value in several ways. Reduced fertiliser requirements, lower dependence on purchased feed, improved yield stability and greater resilience to weather extremes can all contribute to farm profitability, even when grain yield is similar to that of a monocrop.

The economic importance of these benefits depends on the objectives of the farm. For some businesses, reducing production costs may be more valuable

than achieving the highest possible yield. For others, improving feed self-sufficiency or reducing production risks may be the main motivation for adopting intercropping.

The way the harvested crop is ultimately used also influences its economic value. Different post-harvest pathways, including feed use, grain separation and marketing options, are discussed in the chapter “From harvest to market” on page 50.



Farm autonomy and input savings

One of the economic advantages of cereal–legume intercropping is its potential to reduce dependence on external inputs. Legumes contribute nitrogen to the cropping system through biological nitrogen fixation. Depending on the crop combination and local conditions, this can reduce fertiliser requirements and lower input costs. While the size of these savings varies, they can improve overall economic performance, particularly when fertiliser prices are high.

For livestock farms that use intercrops as animal feed, this can also reduce dependence on purchased feed. Producing more feed on the farm may improve self-sufficiency, reduce exposure to volatile feed prices and strengthen the resilience of the farming business.

These indirect benefits are often just as important as grain yield when assessing the overall economic value of an intercrop.

Costs and economic trade-offs

Intercropping can create economic opportunities, but it can also introduce additional costs. Depending on the production system and intended use of the harvest, farmers may face additional expenses related to crop establishment, machinery operations, harvesting or post-harvest handling. Whether these additional costs are justified depends on the benefits generated by the intercrop. For this reason, profitability should always be assessed in the context of the farm's specific objectives and available resources.

It is also important to recognise that markets do not automatically reward intercropping. In many situations, separated cereals and legumes enter the same markets as crops produced in monoculture. Unless buyers offer contracts, premiums or other incentives, farmers may take on additional complexity without receiving a higher price for their products. Economic success therefore depends not only on production costs and yields, but also on whether suitable market opportunities exist for the harvested crop (for more details, see chapter "From harvest to market" on page 50).

Stability and resilience

Economic resilience is about more than achieving the highest possible profit in a single year. It is also about maintaining performance when weather conditions, input prices or market conditions become less favourable.

Observations from the LEGUMINOSE project in Poland showed that intercropping does not eliminate economic risk, but it can help spread risk across different crop components. By combining cereals and legumes, farmers are less dependent on the performance of a single crop and may be better able to cope with variable growing conditions.

Intercropping can also reduce exposure to fluctuations in fertiliser and feed prices by lowering dependence on purchased inputs. As agricultural input markets become increasingly volatile, these benefits may become more important.

For many farms, the value of intercropping lies not only in maximising returns during favourable years but also in improving the ability to cope with uncertainty over the longer term.

Economics and farm performance

Farm autonomy and input savings

Economic performance of intercropping varies between farming systems and production objectives.

In conventional systems, intercropping does not always generate higher profits than cereal monocrops. In some situations, economic advantages arise mainly through improved resilience, reduced input requirements or greater flexibility in crop use rather than through higher yields.

In organic and low-input systems, intercropping often fits naturally within existing management strategies. Because organic production relies less on synthetic

fertilisers and crop protection products, legumes can play an important role in maintaining productivity and nutrient supply. This can improve the overall economic performance of intercrops, although results still depend on local conditions and market opportunities.

There is no single economic result that applies to every farm.

The performance of an intercrop depends on how well it fits within the specific objectives and circumstances of each farming system.

Conclusion

Across the systems studied in LEGUMINOSE, economic success depended less on the intercrop itself than on how it was integrated into the farm business.

Intercropping often delivered the greatest economic benefits where it reduced dependence on purchased inputs, improving farm resilience and increasing management flexibility. Yield remained important, but it was only one part of the economic picture.

Economic performance depends not only on yield, but also on practical factors such as available markets, infrastructure, advisory support and farm objectives. The following chapters examine these wider factors and how farmers can successfully integrate intercropping into their farming systems.



LEGUMINOSE

Barriers to adoption and how to overcome them

Barriers to adoption and how to overcome them

Previous chapters have shown that cereal–legume intercropping can improve productivity, resilience, soil health and resource–use efficiency. Yet despite these benefits, it remains a niche practice across much of Europe.

Experiences from the LEGUMINOSE Living Labs and stakeholder discussions show that many farmers recognise the potential advantages of intercropping. But adopting a new cropping system also depends on markets, machinery, advisory support, practical experience and the wider farming environment.

Understanding the most common challenges is the first step towards overcoming them. LEGUMINOSE stakeholder workshops and farmer surveys identified several common barriers to adoption, as well as factors that can help farmers successfully integrate intercropping into their farming systems (Figure 19).

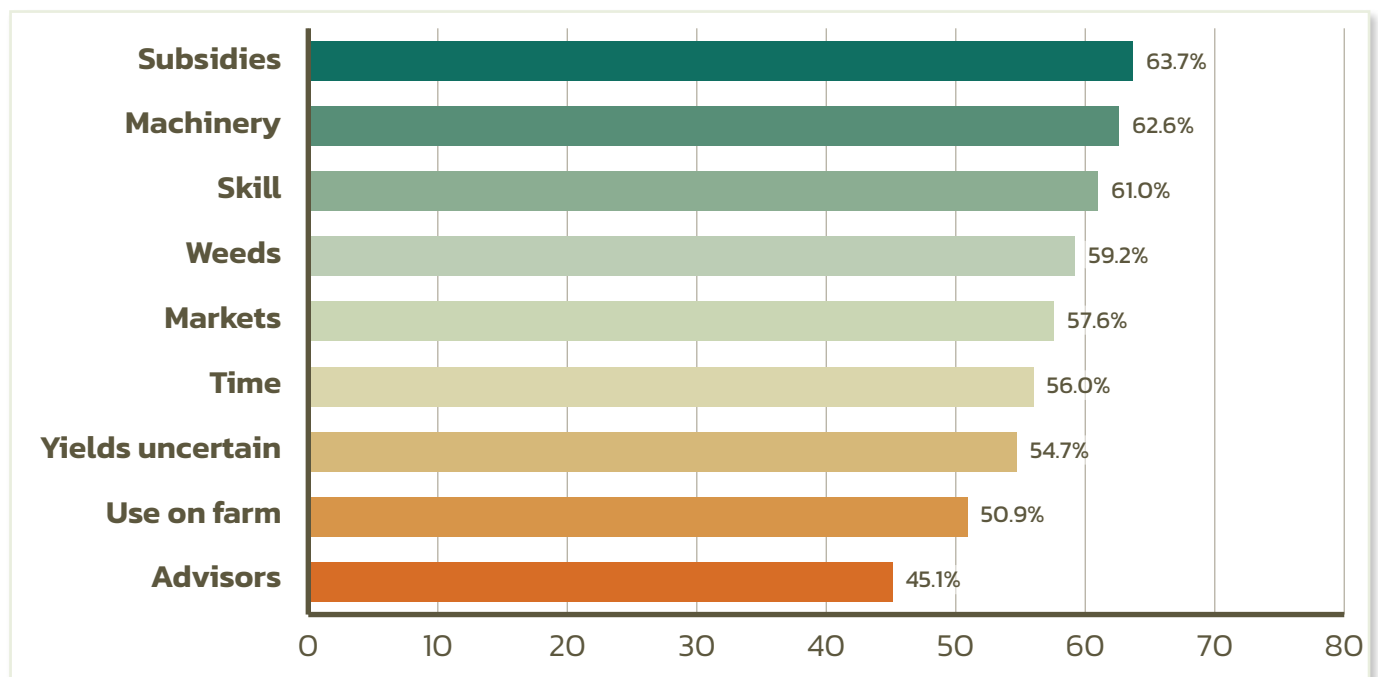


Figure 19: Main barriers to wider adoption of cereal-legume intercropping, identified by farmers and stakeholders across LEGUMINOSE countries



Technical and operational challenges

Intercropping generally requires more planning than growing a single crop.

Farmers participating in LEGUMINOSE identified several practical challenges, including selecting suitable crop combinations, balancing competition between species, managing weeds and synchronising harvest timing.

Farmers highlighted access to specialised machinery or grain separation equipment as an additional constraint. Cleaning, drying and separating cereal and

legume fractions may require additional infrastructure and increase costs. Where such services are unavailable locally, farmers may face logistical difficulties that reduce the attractiveness of intercropping.

These challenges do not make intercropping impractical. Rather, they highlight the importance of planning before sowing and matching intercrop systems to the technical capabilities of the farm and available infrastructure.

Knowledge and advisory gaps

Many farmers interested in intercropping simply lack access to practical, locally relevant information.

Across several LEGUMINOSE countries, farmers identified limited advisory support and a shortage of region-specific recommendations as important barriers to adoption. Although interest in diversified cropping systems is increasing, practical guidance remains limited.

The LEGUMINOSE Living Labs demonstrated how valuable farmer-to-farmer learning can be. The demonstration farms, complemented by field days, peer networks and advisory groups gave farmers the opportunity to observe intercrops under practical conditions, exchange experiences and build confidence before adopting new practices themselves. Seeing intercrops under real farming conditions often provides farmers with the confidence needed to test new approaches on their own farms.

System lock-ins and institutional barriers

Over decades, agricultural systems have become highly specialised. Machinery, storage facilities, advisory systems, processing infrastructure and market arrangements have largely been designed around monoculture production. As a result, farmers often operate within systems that favour established practices and make diversification more difficult.

These so-called “system lock-ins” can slow the adoption of innovative cropping systems. Existing investments in machinery, established supply-chain relationships and familiar management routines can make change appear risky, even when alternatives offer potential benefits.

Institutional factors may also hinder intercropping adoption. In some regions, stakeholders reported that available incentives, support measures and advisory services do not yet fully reflect the specific needs of diversified cropping systems. This can make it harder for farmers to justify experimentation or investment in new practices.

These wider system lock-ins explain why adoption depends on more than individual farmer decisions.

Barriers to adoption and how to overcome them

Market barriers

One of the most frequently identified barriers is the lack of well-developed markets for intercrop products.

As discussed in previous chapters, the economic value of intercropping depends not only on crop performance but also on reliable post-harvest pathways, processing infrastructure and market opportunities. In many regions, these remain underdeveloped, creating uncertainty for farmers considering intercropping.

At the same time, processors and traders often face the opposite challenge: production volumes are too small

and inconsistent to justify investment in dedicated value chains. This creates a self-reinforcing cycle in which limited supply discourages market development, while limited market opportunities discourage farmers from adopting intercropping.

Breaking this cycle will require coordinated action across the value chain, involving farmers, processors, traders, advisors and policymakers.

What helps farmers adopt intercropping?

Despite the above challenges, LEGUMINOSE identified several factors that encourage intercropping adoption (Figure 20).

Environmental benefits are often an important starting point. Farmers and stakeholders recognised the potential of cereal-legume intercropping to reduce dependence on mineral fertilisers and pesticides, improve soil health, support biodiversity and increase resilience to climate variability. Stakeholders also emphasised the potential of intercropping to improve yield stability under drought and other environmental stresses, making it an attractive strategy for climate adaptation in European agriculture.

Economic considerations can further facilitate adoption. Reduced input requirements, greater farm autonomy and improved stability under variable conditions can make intercropping an attractive option, particularly where suitable markets or on-farm uses exist.

Technological developments may further support adoption. Advances in precision agriculture, digital decision-support tools and improved technologies for monitoring, harvesting and grain separation can help reduce management complexity and improve operational feasibility. One example for a digital decision-support tool, developed in the LEGUMINOSE project, is discussed in the chapter “Plan before you plant” on page 55).

Perhaps most importantly, successful adoption depends on knowledge and experience.

Farmers are more willing to adopt new practices when they can learn from trusted advisors, observe successful examples and exchange experiences with other farmers.

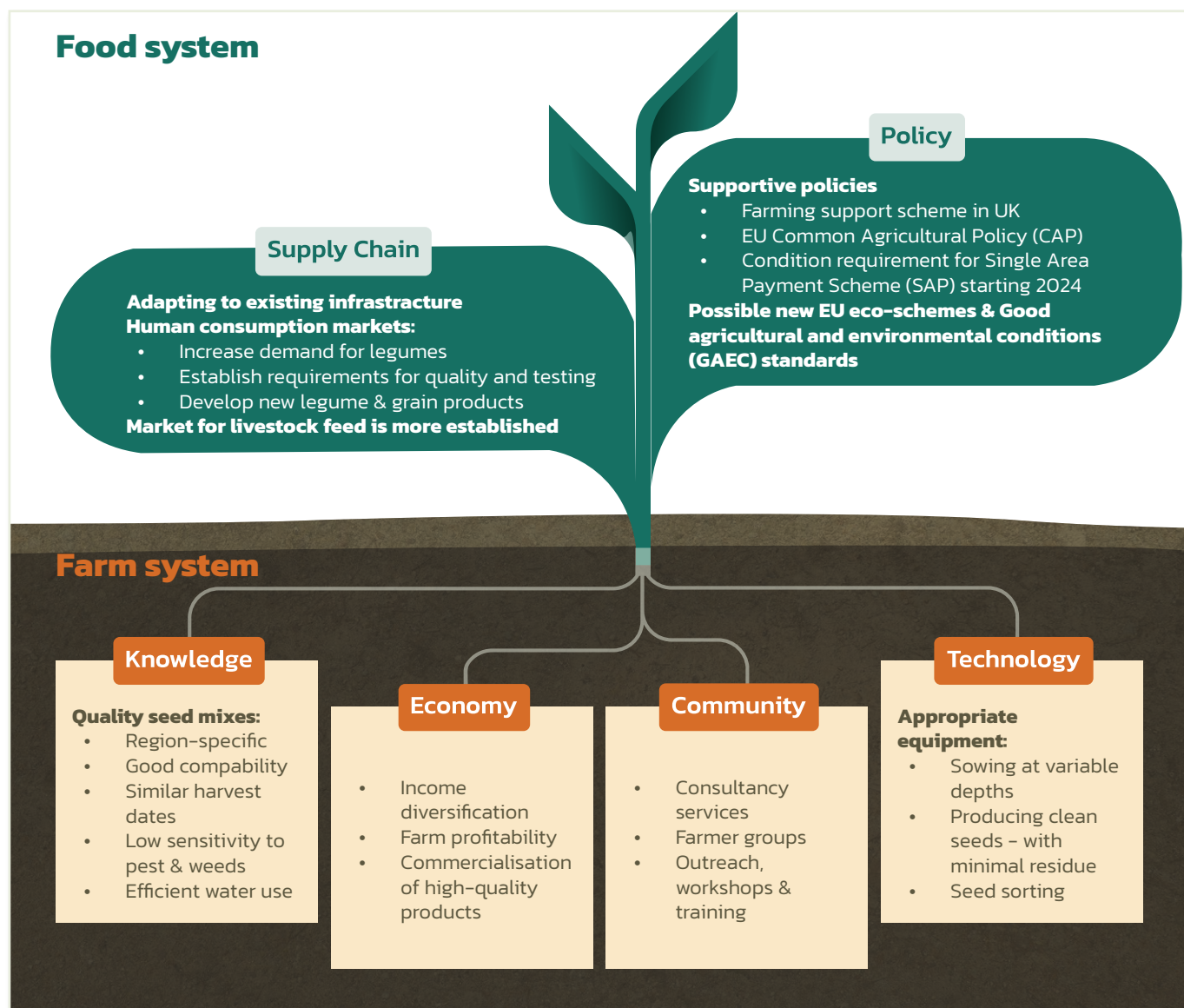


Figure 20: Factors that can support wider adoption of cereal–legume intercropping, based on stakeholder discussions and farmer surveys conducted within LEGUMINOSE.

Conclusion

The barriers to cereal–legume intercropping are often not primarily agronomic. The greater challenge lies in creating the knowledge, infrastructure, markets and support systems that allow farmers to put the benefits of intercropping into practice.

LEGUMINOSE showed that adoption becomes easier when farmers have access to practical advice, peer learning opportunities, suitable equipment, reliable

market outlets and supportive networks. Successful adoption therefore depends not only on individual farmers, but on strengthening the wider systems that support diversified and resilient agriculture. One important part of this wider support system is the development of practical post-harvest pathways and reliable markets for intercrop products. These are explored in the following chapter.

A photograph of a market stall with a large pile of green beans in the foreground. A hand is holding a white plastic bag over the beans. The bag has text on it, including "PLEASE REUSE FOR YOURSELF" and "HAPPY TO DONATE TO CHARITY". The background is slightly blurred, showing other market items and a sign that says "AWS".

From harvest to market



Harvest is not the end of the intercropping journey. The value of a cereal–legume intercrop depends not only on how well it performs in the field, but also on how it is processed, marketed and ultimately used. Unlike monocrops, which usually enter well-established supply chains, intercrops can follow several different pathways. They may be used directly on the farm as feed or forage, sold as mixed grain, separated into cereal and legume fractions for feed or food markets, or processed into higher-value products.

Across Europe, LEGUMINOSE identified a range of successful examples, illustrating how farmers and value-chain actors have developed practical market routes for intercrop products under different farming conditions. These examples show that there is no single pathway to success. The most suitable option depends on the farming system, available infrastructure, product quality requirements and local market opportunities.

The pathway chosen has important implications for both farm management and profitability. Decisions about post-harvest handling, processing and marketing should therefore be considered before sowing, not only after harvest. Thinking about the end market from the outset helps farmers choose appropriate crop combinations, meet quality requirements and identify the infrastructure or partnerships needed to create value from their harvest.

Feed and forage: the most common outlet

Discussions with farmers and value-chain actors across several LEGUMINOSE countries indicated that on-farm feed use remains the dominant outlet for cereal–legume intercrops in Europe. This is particularly true in organic and mixed farming systems, where farmers often grow crops for their own livestock. Mixed crops are also generally more common in organic than in conventional farming systems, reflecting the important role of legumes in organic crop rotations and livestock feeding.

Experiences from the LEGUMINOSE Living Labs highlighted several feed-oriented intercrop systems.

In the Czech Republic, intercrops are commonly used directly as livestock feed. In Germany, intercrop harvests are frequently used on-farm or sold locally for feed. In Denmark, organic farmers commonly grow pea–barley mixtures that are harvested at maturity and used as feed for poultry, pigs and cattle. In Italy, barley–faba bean mixtures are often harvested and used as forage.

Depending on the farming system, the harvested crop may be fed directly as a mixture or separated into cereal and legume fractions before further processing. Using the crop directly can avoid cleaning

From harvest to market

and separation costs while reducing dependence on purchased feed. For livestock farms, this increases farm autonomy and reduces exposure to fluctuating feed prices.

Further processing can improve feed quality. For example, dehulling can increase the nutritional value of both legumes, such as faba beans, and cereals, such as oats. Dehulled oats are already used by some organic farmers, especially in poultry feeding.

Intercrops can also be harvested as green crops for silage or hay. Combinations such as wheat and pea or barley and clover can produce nutritious forage for ruminants and are often used on cattle farms. Experiences shared through LEGUMINOSE workshops in Central Europe and Italy identified on-farm silage production as one of the most practical and widely accepted ways of valorising cereal–legume intercrops.

The importance of the feed market pathway for intercrops is also reflected at the European level. According to the European feed industry association

FEFAC (FEFAC Feed Industry Report, 2025), forage accounts for around 61% of the feed required for European livestock production. Results from the LEGUMINOSE Living Labs reflect this pattern: Around half of participating farmers used intercrops directly as livestock feed or fodder, approximately 40% supplied products to industrial users, while less than 10% targeted human food markets. Feed and forage are therefore likely to remain the most important outlet for cereal–legume intercrops in the foreseeable future.

Case study: Pea–barley intercrops for livestock feed in Denmark

Organic farmers in Denmark commonly grow pea–barley intercrops that are harvested at maturity and used as feed for poultry, pigs and cattle. By producing protein-rich feed on-farm, they reduce their dependence on purchased feed while benefiting from the agronomic advantages of cereal–legume intercropping.

Food markets and niche opportunities

Food markets offer opportunities for some intercrop products, but they are generally more demanding than feed markets.

Across the LEGUMINOSE stakeholder workshops, separation into distinct cereal and legume fractions was repeatedly identified as a prerequisite for accessing most food markets. Food processors consistently reported that they rarely purchase mixed crops directly. Instead, they require clearly defined ingredients such as wheat flour, lentil flour, dried peas or split pulses. As a result, cereal–legume intercrops usually need to be separated before entering most food supply chains.

Separation also supports traceability, quality control and product standardisation. Food manufacturers require reliable raw materials with predictable characteristics, including grain purity, protein content and processing quality. Mixed crops can vary

considerably in their cereal–legume proportions, making consistent product quality more difficult to achieve.

Food processors must also consider practical issues such as allergen management.

For example, gluten-free products cannot be processed in facilities handling wheat, while crops such as soybean require additional precautions because of allergen risks. These considerations make many processors cautious about accepting mixed harvests.

Despite these barriers, LEGUMINOSE identified several promising examples of successful food-market pathways for intercrops. In Italy, an organic farm produces artisan flour from lentils and durum wheat grown in intercrops and markets it directly



through its farm shop. In Scotland, peas produced in intercropping systems have been supplied for use in school meals. These examples illustrate different pathways for creating value from intercrops, ranging from direct marketing and local food products to public procurement schemes.

Before sowing an intercrop intended for food markets, it is worth clarifying a few practical questions. Who will clean and separate the crop? What will the service cost? What quality standards does the buyer require? What price is likely to be paid? Without clear answers, even a successful harvest may prove difficult to market profitably.

Building value chains for intercrops

Even where market opportunities exist, bringing intercrop products to market remains challenging.

One of the main barriers is production volume. Intercrop products are still produced in relatively small quantities across Europe, making it difficult for processors and traders to source consistent supplies.

Quality variation presents another challenge. Mixed crops can differ in cereal–legume proportions, protein content and processing quality. For processors, this creates uncertainty. For farmers, it can reduce bargaining power and make market access less predictable.

Farmer cooperation can help address these challenges. Across the LEGUMINOSE workshops and value-chain discussions, stakeholders frequently highlighted cooperatives, shared cleaning and separation facilities, mobile cleaning units and leased processing equipment as practical ways to reduce costs and improve market access.

By sharing infrastructure and coordinating production, farmers can reduce individual investment costs while building the volumes and consistency required by processors and buyers. This can help improve competitiveness compared with individual farm-level solutions.

Case study: Intercropped flour for local food markets in Italy

An organic farm in Italy grows lentils and durum wheat in intercrops, separates the harvested grains and produces artisan flour for direct sale through its farm shop. This demonstrates how combining on-farm processing with direct marketing can create added value from intercrop products.

Several LEGUMINOSE countries already provide successful examples. In the United Kingdom, crop combinations such as barley–pea, wheat–faba bean and oat–faba bean can enter established food and feed channels supported by contractors, separation services, processors and buyers.

The wider lesson is clear: successful markets depend not only on farmers but also on the wider network of processors, traders, service providers and retailers. Strengthening these connections will be essential for expanding market opportunities for cereal–legume intercrops.

Case study: Building value chains in the United Kingdom

Several cereal–legume combinations, including barley–pea, wheat–faba bean and oat–faba bean, already enter established food and feed supply chains in the United Kingdom. Contractors, grain separation services, processors and buyers work together to provide farmers with practical market routes, illustrating how collaboration across the value chain can support wider adoption of intercropping.

Consumer awareness and product communication

Most consumers are unfamiliar with intercropping as a farming practice. However, many are interested in the broader benefits associated with sustainable food production. However, consumer interest in sustainably produced food continues to grow. Recent surveys suggest that many consumers consider factors such as climate impacts, reduced pesticide use and environmental performance when purchasing food. This suggests that there is growing demand for products associated with more sustainable forms of agriculture, even if consumers are unfamiliar with the specific term “intercropping”.

Stakeholder discussions within LEGUMINOSE suggested that messages related to biodiversity, environmentally friendly farming, local production and reduced

pesticide use are likely to resonate more strongly with consumers than technical descriptions of crop management. Particularly the attribute “reduced use of pesticides” is acknowledged by consumers looking for sustainably farmed products (Liu et al, 2025). This creates opportunities to market products based on the benefits of intercropping rather than the farming practice itself.

As consumer demand for sustainably produced food continues to grow, these wider sustainability attributes may become increasingly important in creating market value for intercrop products.

Conclusion

The value of a cereal–legume intercrop does not end at harvest. How the crop is handled, processed and marketed has a major influence on its final value.

Across Europe, feed and forage remain the dominant outlets, while food markets offer opportunities for specialised products where suitable processing

and marketing channels exist. Successful market development depends on reliable post-harvest infrastructure, consistent product quality, sufficient production volumes and strong collaboration across the value chain.



LEGUMINOSE

Plan before you plant:

Using the LEGUMINOSE
decision-support platform for
cereal-legume intercropping

Plan before you plant

A grower planning a cereal–legume intercrop is not simply asking whether intercropping works in principle. The useful questions are more specific. Will both crops contribute to the harvest? Will the cereal dominate the legume? Which sowing ratio is sensible? Will nitrogen fertilisation improve total production or mainly strengthen the cereal? Would a fully mixed stand or a row/strip arrangement provide a better balance? And how might the same strategy perform in a dry or unusually wet year?

There is no standard answer to any of these questions. Performance depends on the crop pair, their relative densities, soil water-holding capacity, nitrogen supply, seasonal weather and management. A pea–barley mixture that is balanced on one field may become barley-dominated on another. While experienced farmers and advisors understand these interactions, no farm can directly compare every plausible crop combination.

The LEGUMINOSE decision-support platform (DSS) was developed to address this issue. It allows users to select a real field, define a supported intercrop, adjust management decisions and compare the potential outcomes prior to sowing. The platform is freely accessible online, enabling farmers, advisors and researchers to explore different intercropping scenarios using their own field information. The aim is not to replace practical judgement, but to provide a consistent approach to examining realistic alternatives.





Start with the field and the farm objective

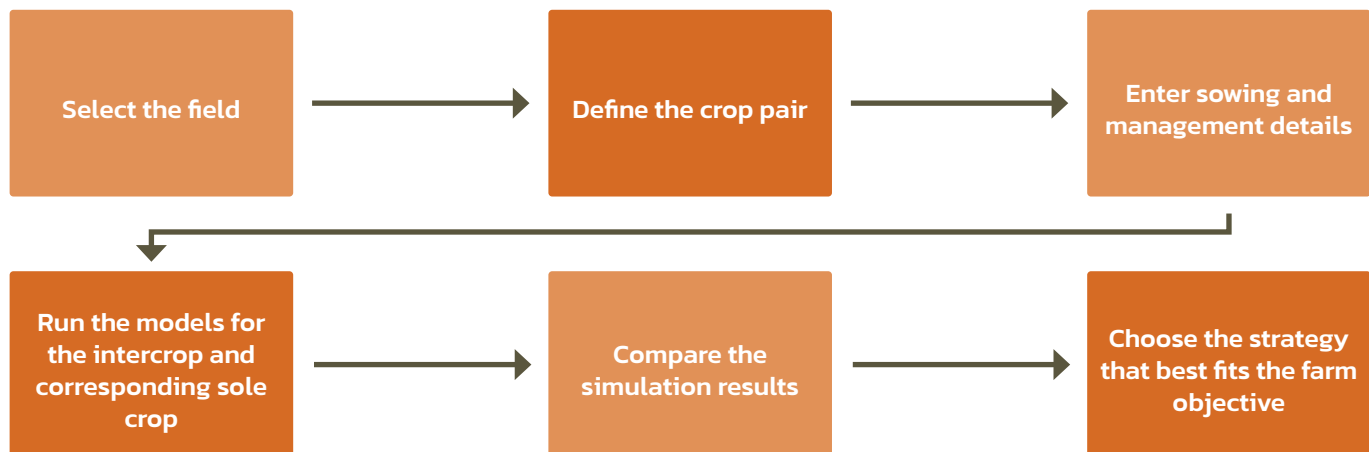
The platform begins with a location rather than a generic recommendation. A field can be drawn on a map or imported from a KML file and divided into plots. The user then defines the crop pair, sowing date, plant densities, spatial arrangement, fertilisation, irrigation and soil conditions.

The first comparison can be created using a small input set. The platform can add location-based soil and weather information, where farm measurements are unavailable. Users with more accurate data can

replace these defaults with local soil analysis results, weather station records, and their own irrigation and fertilisation schedules.

This enables farmers or advisors to get started without having to assemble a research dataset, while experienced users retain control over the assumptions that influence the result. Actual farm operations can also be documented and used as the basis for alternative scenarios.

Each alternative scenario is stored separately. The workflow is straightforward:



The comparison with sole crops is essential. A high combined yield can mask a near-total failure of the legume crop, while a similar total yield may hide a better crop balance or lower nitrogen demand. The platform therefore presents the two crops separately.

Plan before you plant



How much barley is too much? An example

Consider a farmer planning an intercrop of field pea and spring barley.

The main risk may be excessive barley dominance. A high cereal density can improve weed suppression and provide insurance if pea establishment is weak. However, it can also intercept light early on, take up soil nitrogen quickly and leave the peas with too little competitive space.

The farmer first creates a reference scenario using the intended field, sowing date, crop densities, mixed drilling and nitrogen strategy. Copies of the reference scenario can then be used to answer specific questions:

- **Lower barley density:** Does reducing barley pressure increase the pea contribution while retaining most of the combined yield?
- **Moderate nitrogen application:** Does additional nitrogen mainly favour barley and suppress the pea, or increase the total production?
- **Different arrangement:** Does a row or strip configuration improve the balance by changing how the crops share light and below-ground resources?
- **Different weather year:** Does the preferred strategy remain effective under dry, wet and average seasons?

As only one factor is changed at a time, the comparison of scenarios remains interpretable. The outputs

include crop development, component yields and grain protein content, water and nitrogen uptake, and soil balances. The platform enables direct comparisons between intercrops and monocrops and demonstrates how nitrogen fertilisation can benefit the cereal much more strongly than the legume when nitrogen supply is limited.

This changes the decision-making process from asking “Which scenario gives the highest total yield?” to asking more useful questions:

- Does the pea still make a meaningful contribution?
- Is the apparent advantage caused by complementarity or simply by the increased density of barley?
- Does added nitrogen improve or distort the mixture?
- Is the preferred scenario robust across weather years?
- Does the intercrop offer something useful compared with growing the crops separately?

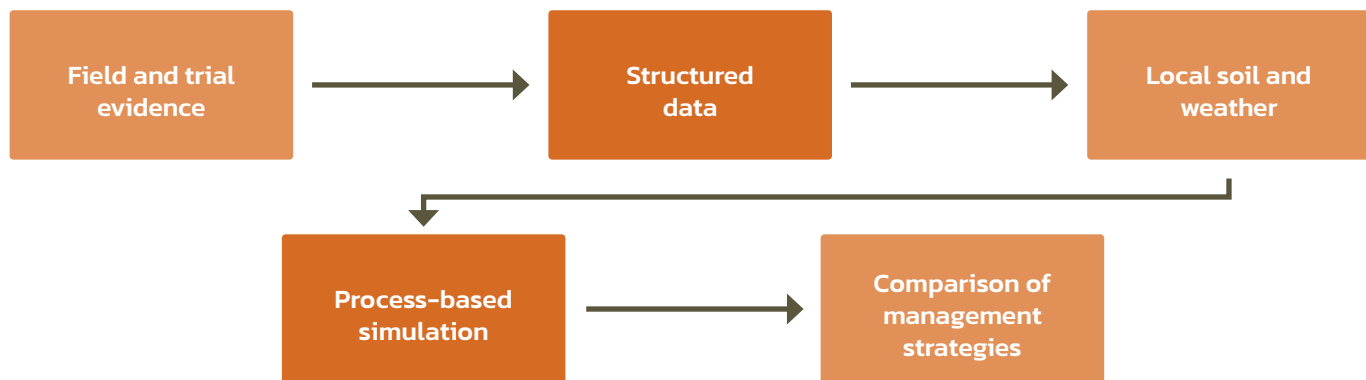
The answer depends on the objective of the farm. For example, a livestock farmer may accept a cereal-heavy mixture for feed security, while another grower may prioritise legume yield, protein, or reduced nitrogen input. The platform illustrates the biological trade-offs involved in these choices.



The LEGUMINOSE DSS is more than another farm app

Many agricultural tools record operations, display weather information or show trial averages. However, they do not answer the central intercropping question: What happens when two crops interact under a defined soil, weather and management scenario?

The LEGUMINOSE decision-support platform connects the full chain:



At the core of the LEGUMINOSE platform is the InterCropping model. It simulates the growth and development of two crops growing together on a daily basis.

The model represents crop development, light interception, biomass and yield formation, water uptake, soil-water balance, nitrogen supply and uptake, biological nitrogen fixation and potential nitrogen transfer from the legume crop to the cereal crop. Both crops run simultaneously and share the same soil resources.

The model also distinguishes between fully mixed stands and row and strip intercropping systems. Therefore, a spatially organised intercrop is not treated as two independent sole crops placed side by side. The interaction itself is part of the calculation.

The LEGUMINOSE InterCropping model was evaluated using LEGUMINOSE field trials and Living Labs together

with independent European datasets. The strongest current evidence is for field pea–spring barley and faba bean–winter wheat.

Access the LEGUMINOSE Decision-Support Platform

The LEGUMINOSE DSS is available online and can be used to explore different cereal–legume intercropping scenarios before sowing. Users can define their own fields and management options, compare alternative strategies and evaluate likely agronomic outcomes under different soil and weather conditions.

Access the platform here: <https://leguminose.farming.software/>

Plan before you plant

Which inputs deserve the closest attention?

A global sensitivity analysis of the InterCropping model identified the crop characteristics that had greatest influence on the simulated yield and grain protein content. These were maximum plant height, timing and duration of phenological stages, effective rooting depth, and minimum and maximum grain nitrogen concentrations. Their importance changed between locations, soils and nitrogen regimes.

The findings are agronomically meaningful: plant height affects competition for light, phenology determines

when crops compete, rooting depth influences access to water, and grain nitrogen characteristics affect protein formation.

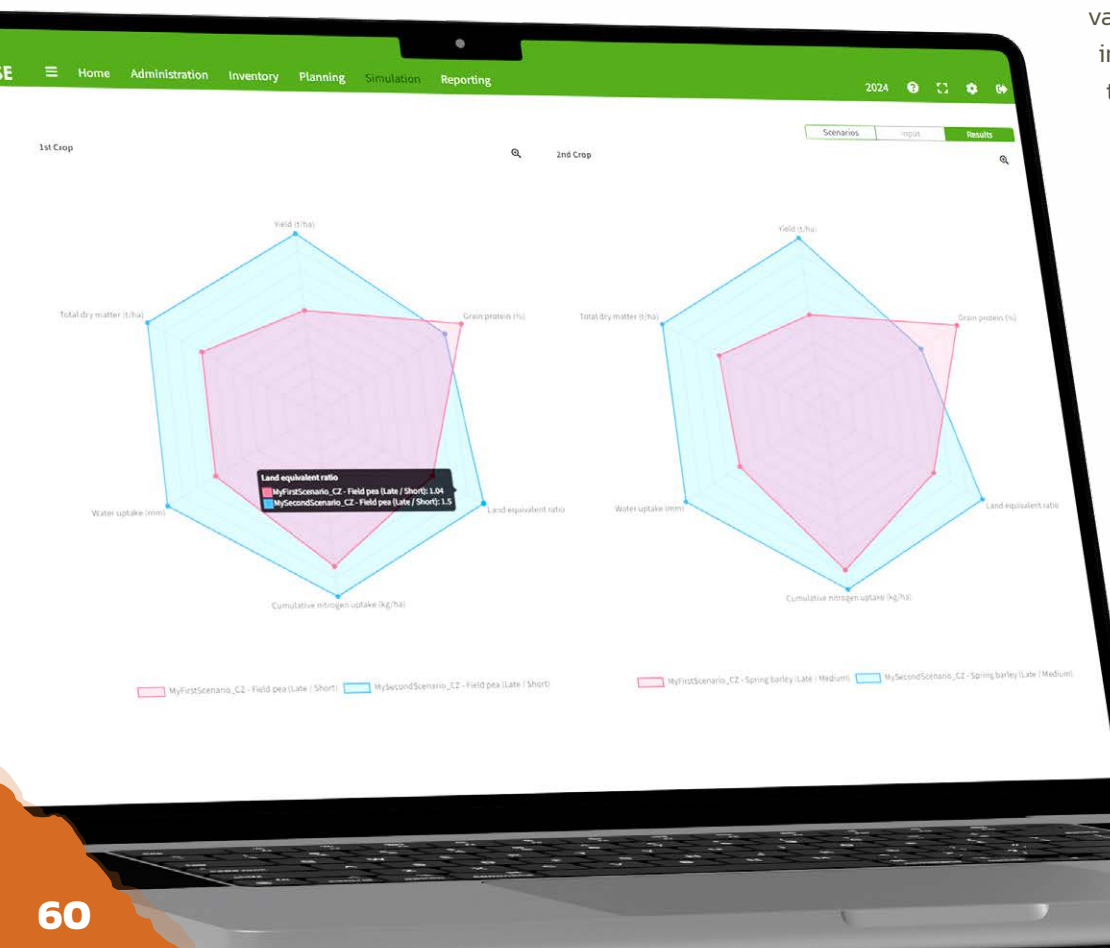
This is why fixed recommendations have limitations. In one field, cereal density and height may be the deciding factors, whereas under dry conditions, rooting depth and the timing of water demand may matter more.

Conclusion

Intercropping is too dependent on crop balance, soil, weather and management for universal recipes. It is also too complex to explore only through trial and error.

The LEGUMINOSE platform offers a practical approach to comparing realistic options before sowing. It combines structured European field evidence, local environmental data and a process-based model of two crops competing for light, water and nitrogen.

For farmers and advisors, the value is direct: it turns complex intercropping decisions into a transparent comparison of field-specific scenarios, helping users to select a stronger starting point and improve it through practice and experimentation.





LEGUMINOSE

Policy and support environment

Policy and support environment

The adoption of cereal–legume intercropping depends not only on decisions made at field level. Farmers also need a supportive environment that reduces risk, enables learning and creates practical routes from production to use or sale.

Previous chapters have shown that intercropping can support resilient farming systems, but also that farmers face barriers related to knowledge, infrastructure, markets and costs. Policy cannot remove all of these barriers, but it can help create conditions that make intercropping easier to test, manage and scale.

Across Europe, intercropping is increasingly relevant to wider policy goals, including climate resilience, biodiversity, soil health, nutrient management and more sustainable protein production.

Financial and policy support for intercropping

The European Union's Common Agricultural Policy (CAP) is the main framework through which farmers receive support for agricultural production and environmental management. Although intercropping is not always explicitly named in policy measures, many CAP objectives are closely aligned with its benefits. Intercropping also fits within broader European policy initiatives that aim to make agriculture more sustainable and resilient. These include the European Green Deal, the Farm to Fork Strategy, the Biodiversity

Strategy for 2030, the Circular Economy Action Plan and initiatives related to carbon farming, soil health and European protein production.

The specific opportunities available to farmers vary between Member States. Farmers interested in intercropping should therefore check with local advisors, paying agencies or agricultural authorities to identify which measures apply in their region. Support may be available through instruments such as:



eco-schemes
that reward
environmentally
beneficial farming
practices



agri-
environment-
climate measures



support for
sustainable
nutrient
management



measures
promoting crop
diversification
and resilience



investments
in innovation
and farm
modernisation



Advisory systems

As previously discussed, access to practical knowledge is one of the key factors influencing adoption. Policy and public support can strengthen this knowledge base by investing in advisory services, demonstration activities, farmer networks and participatory research.

This support is especially important because intercropping is highly context-specific. Farmers need locally relevant information on crop combinations, sowing strategies, harvest management and post-harvest options. Research projects, Living Labs and farmer-led trials can help generate this knowledge under real farming conditions.

Innovation support also matters. New tools and technologies, including decision-support platforms such as the LEGUMINOSE DSS described in the previous chapter, precision agriculture, improved harvesting systems and grain separation technologies, can reduce uncertainty and make intercropping easier to manage. Continued investment in research and innovation can help reduce uncertainty, improve management recommendations and support wider adoption of intercropping across Europe.

Supporting market development

Market access remains one of the main constraints to wider adoption. From a policy perspective, the key issue is how to support the infrastructure and cooperation needed to make these markets function.

Public support can help by encouraging investment in cleaning, separation, storage and processing capacity, especially where individual farmers cannot justify such investments alone. It can also support farmer cooperation, local value-chain development and initiatives that connect producers with processors, traders, retailers and end-users.

Stakeholders involved in LEGUMINOSE emphasised that adoption requires coordinated action across the food system. Farmers, advisors, processors, retailers and policymakers all influence whether intercrop products can move efficiently from field to market. Strengthening these links can help create more stable demand and reduce the risk faced by farmers.

Supporting market development

Farmers and advisors interested in exploring intercropping do not need to start from scratch. Across Europe, a growing range of support resources is becoming available through advisory services, research organisations, farmer networks and practical demonstration activities.

The LEGUMINOSE project has contributed to this knowledge base through field trials, Living Labs, training materials, decision-support tools and practical guidance. These resources are designed to help farmers and advisors better understand the opportunities and challenges associated with cereal-legume intercropping and support informed decision-making.

Conclusion

The experience gathered through LEGUMINOSE shows that intercropping becomes more practical when policy, research, advice and value chains work together. Farmers remain central to adoption, but they should

not have to carry the transition alone. Stronger support systems can help cereal–legume intercropping move from promising practice to a more widely used farming strategy.





LEGUMINOSE

Key recommendations

Key recommendations

Throughout this handbook, we have shown that cereal–legume intercropping is neither a universal solution nor a niche curiosity. Under the right conditions, it can improve productivity, increase resilience, reduce dependence on external inputs and contribute to more sustainable farming systems. At the same time, successful intercropping requires careful planning, appropriate management and realistic expectations.

Perhaps the most important lesson from the LEGUMINOSE project is that successful intercropping is not achieved by changing a single field operation. It comes from designing a farming system in which crop choice, management, markets, advice and support work together.

The following recommendations summarise the main lessons from the project and provide practical guidance for farmers, advisors and policymakers.

Planning for harvest from the beginning

Intercropping is most successful when it is adapted to the objectives and conditions of each individual farm. Rather than searching for a universal recipe, farmers should focus on designing systems that fit their own production goals and available resources.



Start with a clear objective. Decide why you want to intercrop before choosing crop species. Your objective may be to improve yield stability, reduce fertiliser use, produce home-grown feed, suppress weeds, improve soil health or access new markets. A clear objective makes later management decisions much easier.



Choose crop combinations that suit local conditions. Successful intercrops depend on climate, soil, machinery and farming system. Species that perform well elsewhere may not be the best choice on your farm. Where possible, build on local experience and advice.



Plan beyond sowing. Consider harvest, storage, cleaning, separation and marketing before planting the crop. The intended use of the harvest should influence species selection, sowing strategy and management throughout the season.



Start small and learn. Many successful farmers began by testing intercropping on a small area before expanding. Small-scale trials reduce risk while providing valuable experience under local conditions.



Use available support. Take advantage of advisory services, demonstration farms, farmer networks and decision-support tools. Learning from other farmers can often be as valuable as information from research.



Intercropping checklist

Before establishing a cereal–legume intercrop, ask yourself the following questions.

Objectives

- ☐ What do I want to achieve?
 - Higher yield stability?
 - Lower fertiliser use?
 - Better weed suppression?
 - Home-grown feed?
 - Access to food markets?
 - Improved soil health?

Harvest and marketing

- ☐ How will I use the harvest?
- ☐ Will I need cleaning, separation or further processing?
- ☐ Are suitable buyers, processors or on-farm uses available?

Crop selection

- ☐ Which cereal and legume are well suited to my climate and soil?
- ☐ Which combinations have performed well in my region?
- ☐ Does the chosen intercropping system (mixed, row or strip) match my objectives?

Advice and support

- ☐ Have I explored advisory services, farmer networks or decision-support tools?
- ☐ Are financial support measures available in my region?

Getting started

- ☐ Would it be sensible to begin with a small trial before expanding?

Farm management

- ☐ Can I establish and manage the intercrop with my available machinery?
- ☐ Have I considered sowing depth, seeding rates and crop competition?
- ☐ Do I understand how weeds, pests and diseases will be managed?

Recommendations for advisors and extension services

Advisors play a central role in helping farmers evaluate whether intercropping fits their farming system and how it can be implemented successfully.



Provide locally relevant guidance.

Practical recommendations should reflect regional soils, climate, cropping systems and available machinery rather than general principles alone.



Support whole-farm decision making.

Help farmers consider agronomic performance alongside economics, harvest management, market opportunities and long-term resilience.



Promote farmer learning. Demonstration farms, Living Labs, field days and peer-to-peer exchange build confidence and help farmers learn from practical experience.



Use digital tools as part of advisory support. Decision-support tools can help compare options and reduce uncertainty, but they work best when combined with local knowledge and field experience.

Recommendations for policymakers

Successful adoption depends not only on individual farmers but also on the wider environment in which they operate.



Reward diversified cropping systems.

Support measures should recognise the contributions of cereal-legume intercropping to soil health, biodiversity, climate resilience and more efficient nutrient use.



Strengthen advisory and knowledge-exchange systems.

Investment in advisory services, demonstration activities, farmer networks and participatory research helps translate scientific knowledge into practical farming solutions.



Support innovation and infrastructure.

Continued investment in research, digital tools, grain cleaning and separation facilities, processing capacity and other innovations can reduce practical barriers to adoption.



Strengthen value chains.

Farmers need reliable routes to market. Supporting cooperation between producers, processors, retailers and food manufacturers can help create stable demand for intercrop products and improve their economic viability.



LEGUMINOSE



Key recommendations

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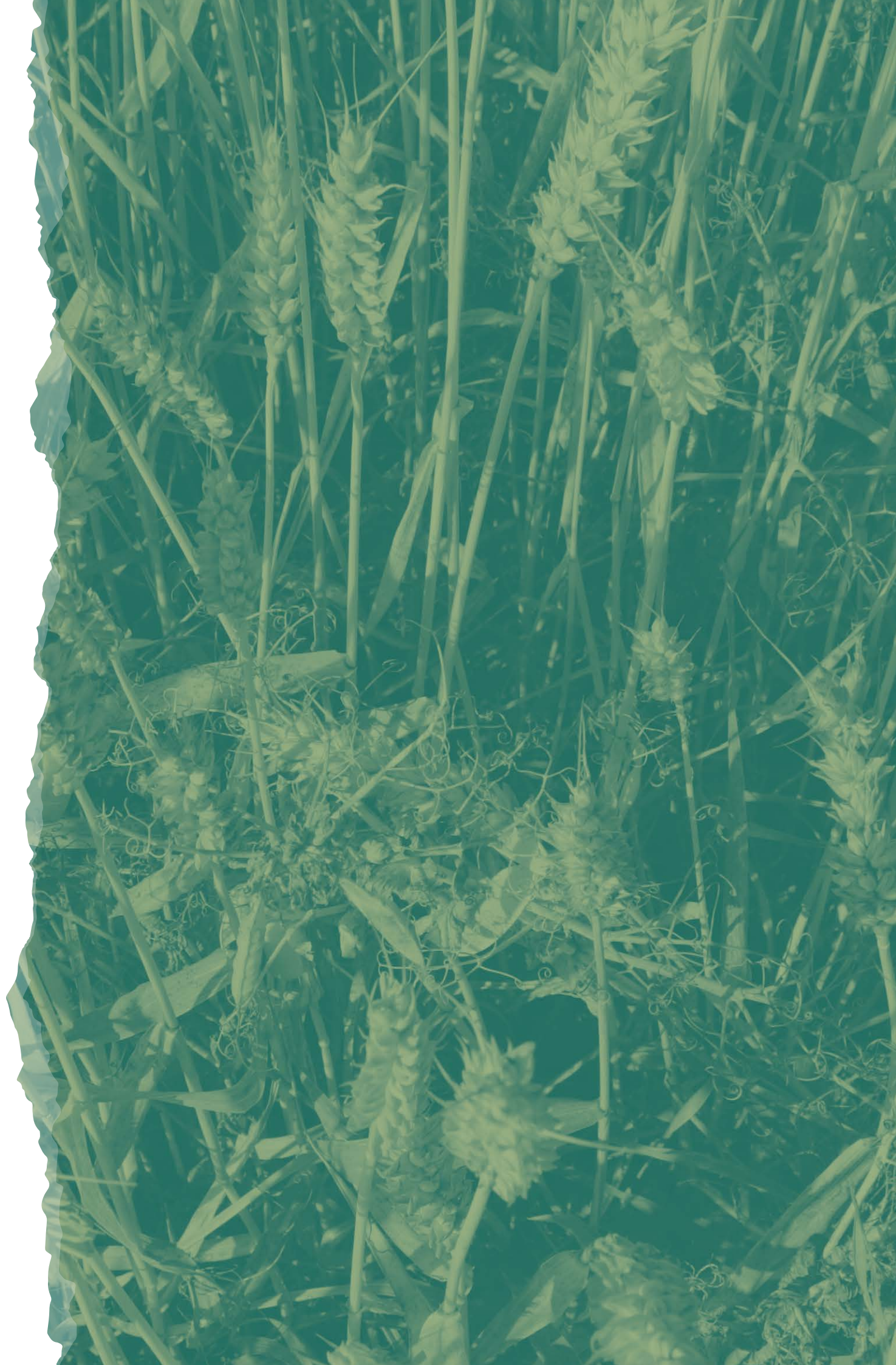
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For more information about
the project visit our website:
www.leguminose.eu



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