



Designing sustainable, resilient, and scalable supply chains for plant-based proteins

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Problem Statement

Europe's shift towards plant-based proteins necessitates expanding domestic production. However, to achieve this, it is important to first scale up crop supply chains, which currently remain underdeveloped, due to several key barriers across the EU. These include limited processing infrastructure and specialised facilities for legume post-harvest and processing ([see](#) 3.1.6), uncertainty in end-use allocation between food and feed, which complicates balancing volatile feed markets with rising high-value food protein demands, and increased climatic vulnerability leading to higher crop loss risks. Since legume supply chains are not yet established, determining the required infrastructure is challenging ([see](#) 3.1.6). It remains uncertain whether a decentralised supply chain design of local hubs or a centralised industrial cluster is more viable. This lack of a clear strategic framework limits the growth of new protein products and deters the long-term investments necessary for EU self-sufficiency in plant proteins. These issues decrease economic viability, elevate spoilage risks, and limit legumes' role in achieving EU protein self-sufficiency.

Solution

Our work combines insights from two complementary modelling studies (Figure 1):

1) Intercropping and lodging risk: A two-stage stochastic optimisation model evaluates how intercropping peas and faba beans, under wind-related lodging uncertainty, affects downstream supply chain design. The model identifies efficient configurations for (de)centralised sorting, processing, and allocation of beans for food-grade or feed uses. The model can be applied to different mixed-crop systems, climatic regions, and countries across Europe. We applied the model to a case study in Italy.

2) Infrastructure resilience and scalability: A multicriteria decision analysis framework evaluates legume supply chains, specifically focusing on the trade-offs between centralised vs. decentralised network designs. The developed model is applied to the case study of faba beans in Ireland, as a

representative of scaling up underutilised crop legumes. The study explores the transition from increased land use and identifies the infrastructure requirements for drying and storage to reduce spoilage risks, along with food and feed processing techniques.

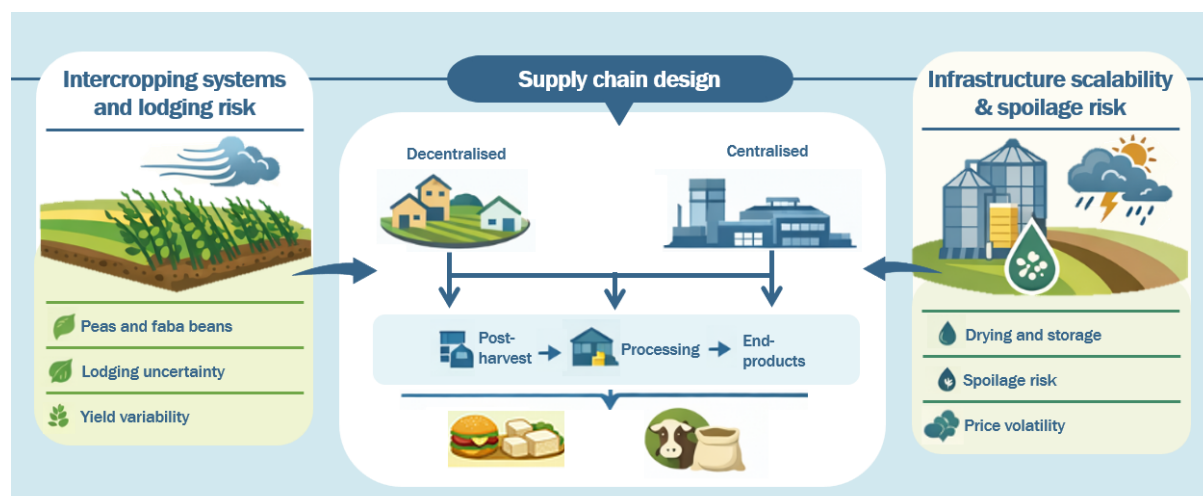


Figure 1: Framework for legume supply chain resilience. The conducted studies link agro-climatic risks and infrastructure scalability (right) to optimise supply chain design and end-product allocation.

Together, these works provide a system-level assessment of how agronomic practices, infrastructure, and end-use choices shape the sustainability and resilience of EU legume supply chains.

Benefits

Across both studies, the modelling results show that:

- **Enhanced economic value:** Shifting from low-value bulk feed to higher-value feed-grade and food-grade uses (e.g., protein isolates) increases the "economic density" of domestic land use, making legume cultivation more competitive with imported crops such as soy.
- **Waste reduction:** Lower spoilage and higher economic returns are achieved when drying and storage capacity are adequate and strategically built to buffer against high-moisture "wet" harvest years.
- **Climate resilience:** Diversified processing networks allow for diverting weather-damaged crops to feed while preserving high-quality batches for human consumption.
- **Scalability roadmap:** The research identifies the production thresholds where processing technologies such as dry fractionation, wet extraction, and heat treatments become viable.

Practical recommendations

Based on the combined evidence:

- **Support dual-purpose infrastructure:** Invest in flexible drying and processing facilities capable of handling both pure and intercropped legume streams.

- **Promote intercropping systems** where agronomically suitable, as they introduce a broader harvest window for farmers with the potential to stabilise yields and reduce losses due to inclement weather in the ~4 weeks before harvest, when the crop is vulnerable.
 - **Develop market incentives** for human-consumption legume products to shift beans from low-value feed uses.
 - **Incentivise food-grade processing:** Establish food-grade processing facilities to increase the value of domestically grown legumes and reduce reliance on imported protein sources, while balancing the monetary gains with environmental impacts associated with transport and production.
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Environmental Impact

The modelling results show that:

- Local processing helps cut transport emissions and prevents spoilage waste by handling high-moisture crops close to the farm.
- Our approach highlights the trade-offs between conflicting goals, such as environmental impact and economic benefits.
- Processing food-grade crops at high values boosts the "protein yield per hectare" for human consumption, decreasing the total land needed to support European nutritional requirements.
- Supporting the economic sustainability of (inter)crop legumes, the models promote the growth of nitrogen-fixing crops, which reduces dependence on synthetic fertilisers.

Together, these effects foster more sustainable, circular, and resilient plant-protein supply chains.

Weblinks (FSH will incorporate the links once the Practice Abstracts are posted online)

<https://edepot.wur.nl/692165>

<https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2021.692137/full#B17>

About this practice abstract and VALPRO Path

These practice abstracts were elaborated in the VALPRO Path project based on the EIP AGRI abstract format. VALPRO Path, a Horizon Europe project spanning 4 years, from September 2022 until August 2026. With the participation of 22 partners from 9 countries, VALPRO Path is developing fresh possibilities, validating and showcasing ways to enhance plant protein production for food and feed in the EU.



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Project website: <https://valpropath.eu/>