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Report

# European protein diversification

## Growing opportunities for farmers

Institute for European Environmental Policy

Institute for European Environmental Policy

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# EXECUTIVE SUMMARY

An unprecedented series of global food system crises is impacting European agriculture, affecting agricultural production and the livelihoods of European farmers. At the same time, the crucial but uncertain transition towards a more sustainable and healthier agrifood system adds pressure to farmers and the sector. This research explores how European farmers, together with the wider food industry, scientists and policy makers, can successfully anticipate this transition by turning challenges into sustainable business model opportunities.

### Key impact areas for European protein diversification

Protein diversification, defined as rebalancing shares of animal-sourced, plant-based and novel proteins within the agrifood system, is increasingly proposed as an effective strategy for Europe to simultaneously address multiple impact areas. This report identifies five key areas where European protein diversification could have a substantial positive effect (see Annex 1 for an assessment). While the environmental, planetary resource, health, and animal welfare impacts are well documented in literature, the socio-economic effects on Europe's agricultural sector remain largely underexplored.

### The socio-economic impacts on farmers from protein diversification

Two scenarios for 2030 simulating a 10% to 30% shift of the average European diet to the EAT-Lancet reference diet are used to assess potential impacts from protein diversification on agricultural production, producer prices, trade, farmers' income and related GHG emissions. These scenarios imply an increase in fruits, vegetables, nuts and legume consumption, and a reduction in animal-sourced foods and sugars.

Based on existing simulations, results from these scenarios indicate that production and producer prices for animal-sourced food would likely decline, while plant-based foods such as fruit, vegetables and legumes would increase sharply. The total production of all major European crops is expected to increase, offsetting declined demand for animal feed. The decline in European livestock production is expected to be proportionally smaller than simulated demand changes, due to moderating effects from international trade (i.e. increasing both animal-sourced exports and plant-based imports).

In terms of impacts, one implication of this shift is that emission reductions could be "exported" abroad. Therefore, the climate change impact of European dietary change could be primarily driven by GHG reductions outside the EU, with only limited reductions within Europe. This is due to increased carbon-intensive exports of animal-sourced foods and lower carbon-intensive plant-based production in non-EU countries. In terms of other impact areas, the relatively small expected reduction in European livestock production would limit the

benefits on European environmental, planetary resource, and animal welfare areas.

The simulations indicate mixed results for farmers' incomes. The dietary shift scenarios impacted farmers' income, but without scientific consensus on whether it would be positive or negative on an aggregated European level. However, results suggest a high level of heterogeneity of income impacts across Member States, regions and farming systems. Without interventions, farmers specialized in livestock are expected to face a substantial loss of income, while farms specialized in fruits and vegetables are expected to substantially increase their income. This could be amplified by 'shock effects' when agricultural production factors are not able to timely diversify in line with demand changes, or when these changes are not possible, underlining the need for policies that support all farmers throughout this transition.

### Perspectives on socio-economic opportunities and risks for farmers

The socio-economic impacts of protein diversification on farmers will largely depend on their ability to adapt to shifting dietary demands. If farmers are able to successfully diversify their production in response to changing demand, potential losses from lower animal-sourced demand and animal feed can be offset with higher plant-based production and producer prices. However, there are more opportunities and risks for farmers at play. For example, farmers might exploit new revenue opportunities through improved soil health through nitrogen fixation by legumes, valorising agricultural side-streams such as fermentable sugar feedstock for microbial fermentation or other bio-economy purposes.

Diversification could be an opportunity for farmers, but it can involve major and complex changes. Diversification to mixed or arable farming can be hindered by (perceptions of) financing and farm environment inflexibility, owing to (perceived) unsuitable topographic, cultural, investment or farm-specific characteristics. These perceptions can be driven by behavioural and socio-cultural influences as well, such as scepticism regarding the magnitude of dietary change, polarized views on plant-based diets and the importance of social status in rural areas. Despite its significance, surprisingly limited research considers the perspectives and needs of European farmers regarding diversification, including the potential of generational renewal and new entrants.

### Unlocking profitable legume business models for farmers

A key prerequisite for farmers to diversify to new opportunities is to ensure that there are profitable business models. Using the illustrative example of legumes, four key barriers are identified limiting profitable legume cultivation in Europe, with regional and value chain variations. Key challenges include volatile producer prices, driven by fluctuating demand, and low, unstable yields. Additionally, opportunity costs stem from the comparative advantage of major European crops

and livestock, while switching costs arise from required investments to adapt farming systems and infrastructure that are currently specialized for major crops. Options to address these barriers are identified that unlock profitable legume business models for farmers, while generating ecosystem benefits.

### EU policy recommendations

Empowering European farmers to drive and benefit from protein diversification requires long-term commitment and decisive action from policy makers, food industry, the agricultural sector and consumers. Insights from this report translate into **five key policy recommendations**, which are complementary to other initiatives aimed at strengthening the role of farmers in Europe.

1. Develop an **EU protein diversification strategy**, for food and feed, with clearly articulated impact targets, including economic benefits for farmers, aligned with adjacent policy areas (e.g., bio-economy).
2. **De-risk** farmers' efforts to diversify into plant-based opportunities, and **recognize and reward ecosystem benefits** generated by these initiatives.
3. **Support diversified value chains** through public procurement and enhanced value chain collaboration with suitable contractual arrangements and fair pricing for farmers.
4. Create an **EU plant-based innovation cluster** to effectively unite public, industry, research, and civil society stakeholders to accelerate plant-based food innovation.
5. **Make sustainable and healthy foods the easy option** for European consumers by creating a more equitable level playing field between plant-based and animal-sourced foods.

# 1. INTRODUCTION

Europe's food system is confronted with an unprecedented series of crises that are undermining its capacity to provide sustainable, healthy and equitable food. Although no 'silver bullet' exists to solve these crises at once, protein diversification is increasingly proposed as an effective strategy to mitigate multiple crises in parallel, such as reducing GHG emissions and enhancing food security (Rieger et al, 2023; van Zanten et al., 2023).

Protein diversification, defined as rebalancing the shares of animal-sourced, plant-based and novel proteins in the agrifood system, requires a 'shift' to more sustainable, healthier and equitable food production, processing and consumption. A considerable variation in the definition and objectives for this 'shift' currently co-exists, such as between advocates for a fully plant-based versus a flexitarian diet (Duluins and Baret, 2024; Pyett et al., 2023).

Protein diversification is arguably already well underway in Europe, but a political consensus seems to be hindered by among others uncertain socio-economic implications on the agricultural sector. European farmers, workers and rural communities are significantly impacted by crises within the food system, such as yield losses due to soil degradation and extreme weather and might also face socio-economic uncertainty from a diversification towards a more sustainable system. Surprisingly, research on socio-economic implications from protein diversification on European farmers and pathways to enhance their resilience remains limited (Craft and Pitt, 2024; Hristov et al, 2024).

### Research objective and structure

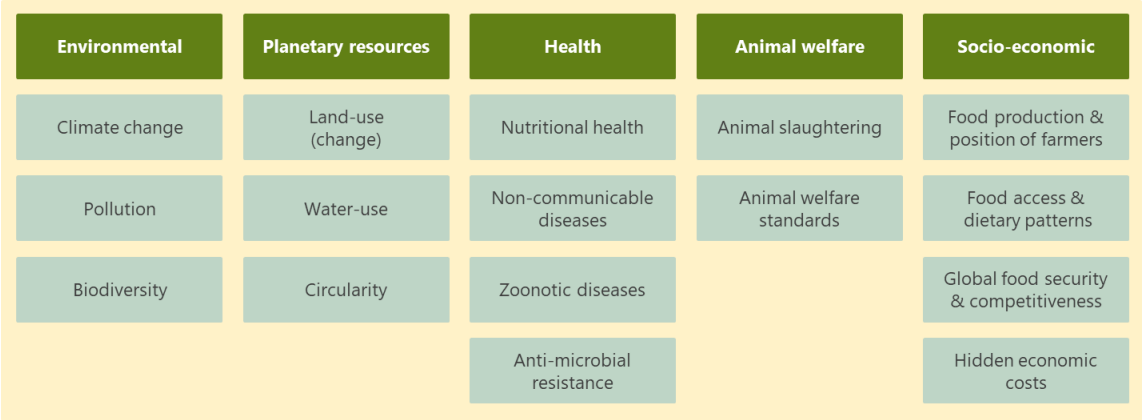
This report aims to better understand how European farmers can be prepared to cater to a shift towards healthier and more plant-based European diets. It is meant as a starting point to **explore how European farmers can be empowered to benefit from European protein diversification while driving positive environmental, planetary resource, health and animal welfare impacts**.

The report outlines a framework to understand the potential of European protein diversification across five key impact areas. It then assesses the potential socio-economic impacts on farmers by using scenarios simulating a shift towards increased plant-based food consumption in 2030. Next, it explores the importance of enabling farmers and value chains to diversify in line with demand changes to avoid socio-economic risks and to benefit from new opportunities. The subsequent two chapters examine the case of diversification with legume crop cultivation by identifying structural barriers and options to lower them. Finally, five key European policy recommendations are proposed to empower European farmers to drive and benefit from European protein diversification.

# 2. KEY IMPACT AREAS FOR EUROPEAN PROTEIN DIVERSIFICATION

Protein diversification is increasingly proposed as an effective strategy to mitigate multiple crises in parallel, driven by their interconnections within agrifood systems. A literature review on the impact from protein diversification indicated its substantial potential to mitigate environmental, planetary resource, health, animal welfare and socio-economic challenges in parallel (Figure 1).

***Figure 1: framework with key impact areas for protein diversification***




*Source: authors own compilation, based on sources including* Verkuijl et al. *(2023), European Parliament (2023),* Godfray et al., 2018, Pyett et al., 2023

One of the key findings from the review (Annex 1) was the potential of reducing the share of carbon-intensive animal-sourced proteins in European food production and consumption, through reducing over-consumption or diversification to more sustainable plant-based or novel proteins. This reduction holds substantial positive effects across these five key impact areas, from enhancing food security to animal welfare, yet its socio-economic implications on the agricultural sector remain largely unclear.

A key example is provided by the EAT-Lancet Commission that developed a global reference diet aiming to create parallel positive health, environmental and animal welfare effects (Willet et al., 2019). Leveraging synergies between impact areas provides the opportunity to maximize the overall impact and drive consensus between different protein diversification narratives. However, there can be barriers to creating synergies that need to be resolved, such as for the environmental and health benefits of legumes versus a lack of a viable business model for European farmers in certain regions to cultivate these minor crops (Degieter et al., 2023; Brannan et al., 2023). As stated before, protein diversification is not a 'silver bullet' and should be regarded as largely complementary to other effective sustainability measures for all impact areas shown in Figure 1 (Van Zanten et al., 2023).

# 3. SOCIO-ECONOMIC IMPACTS ON FARMERS FROM PROTEIN DIVERSIFICATION

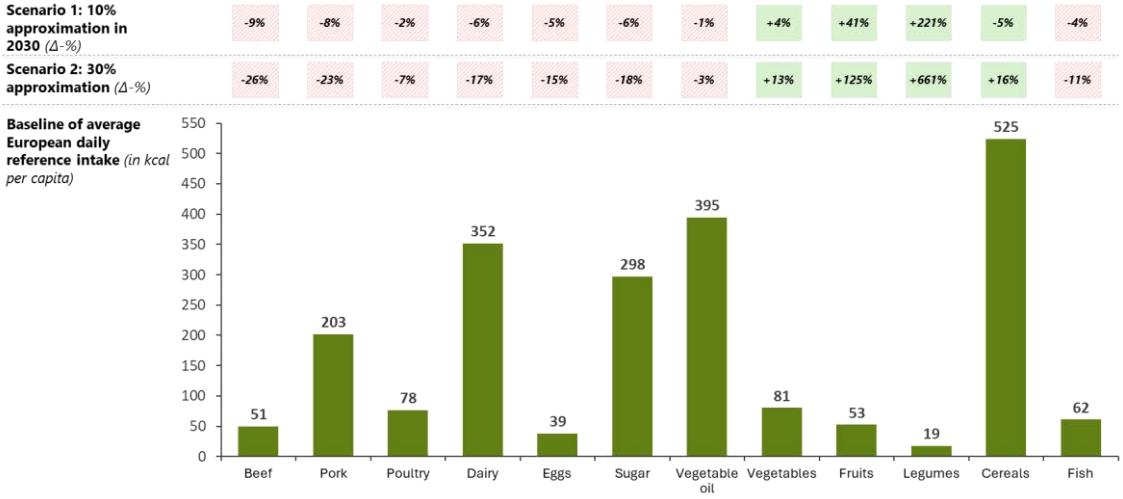
Over the last decade, scientific research on protein diversification has had a predominant focus on environmental, planetary resource, health and animal welfare impact areas (IPCC, 2007; Godfray et al., 2018; Willet et al., 2019), while socio-economic implications for the agricultural sector have been largely underexplored. A few recent pioneering exceptions (Geibel et al, 2021; Hristov et al., 2024; Rieger et al., 2023) have shown how economic modelling of dietary change scenarios could provide complementary insights into socio-economic impacts from protein diversification. This chapter explores the results of these studies to better understand what the socio-economic impacts on farmers could be if the average European diet would become healthier and more sustainable. The aim is to provide a starting point to better understand how farmers can economically benefit from protein diversification, while simultaneously creating positive environmental, planetary resource, health and animal welfare impacts.

## 3.1 Description of scenarios for healthier and more sustainable diets

This chapter explores two hypothetical European food consumption scenarios for the year 2030, which simulate a shift towards more sustainable and healthier diets. The two simulated scenarios close the gap to different degrees between the current average European diet and the EAT-Lancet global reference diet, which serves as benchmark of a healthier and more sustainable diet (Willet et al., 2019). The 'gap' between the average European and EAT-Lancet diet is linearly closed by both scenarios, with 10% in the first scenario and 30% in the second scenario. The corresponding dietary changes, which dependent on the size of the 'gap', per food category compared to a baseline of an average European diet are shown in Figure 2. Shifting towards the EAT-Lancet diet requires predominantly an increase in fruits, vegetables, nuts and legumes consumption, while animal-sourced foods and sugar are reduced (Willet et al., 2019).

The insights in this chapter are building upon two recent studies by the Thünen Institute and the Joint Research Centre of the European Commission, which are both using the partial-equilibrium CAPRI model to simulate economic impacts from stand-alone European dietary change scenarios, without applying any structural changes in the agricultural sector, policies or regulations (Hristov et al., 2024; Rieger et al., 2023). The scenarios intentionally exclude other pathways to sustainable diets, such as reducing food waste and over-consumption, to keep a focus on rebalancing plant-based and animal-sourced proteins. These studies are therefore simplifying the complexities around protein diversification and are not meant as a forecast for European food consumption.

**Figure 2: Relative changes from a baseline of a European daily average per person food intake to two scenarios for 2030 (in %, kcal)**

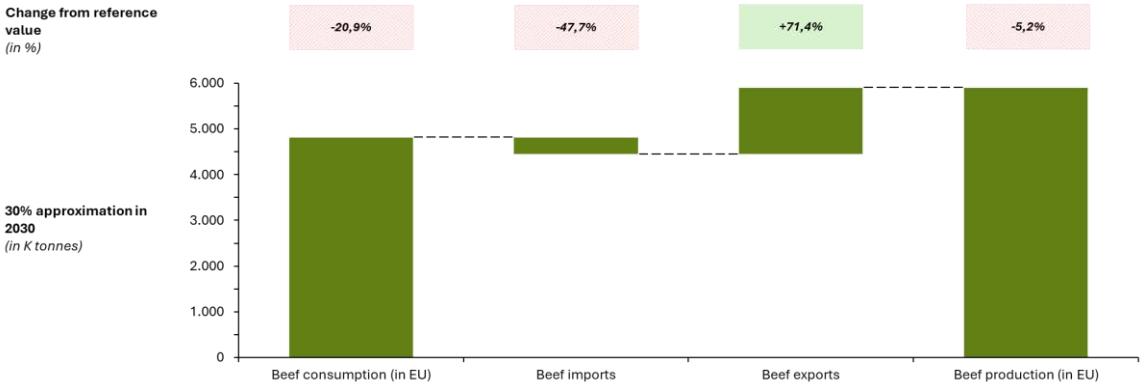



*Source: author's visualization based on accessed online annex from Rieger et al., 2023.*

## 3.2 Impact on primary agricultural production and international trade

Without policy interventions, lower simulated demand for animal-sourced foods is expected to reduce European livestock production, although proportionally less than the magnitude of demand changes. As illustrated in Figure 3, scenario results suggest that production volume changes are moderated by international trade (Rieger et al., 2023).[1]

**Figure 3: Effects from scenario 2 (30% approximation) on a baseline of current European beef consumption, production, and international trade (in Kts, %)**




*Source: calculations based on CAPRI model output received from Jörg Rieger in February 2025.*

In both scenarios, the largest production reductions are projected for beef, pork, dairy and sugar, with poultry production slightly reduced. The largest increase in agricultural production is projected for legumes, while all major EU crops

[1] Substitution by bio-ethanol production is expected to provide a moderation effect as well, but to a lesser extent than international trade (Rieger et al., 2023).

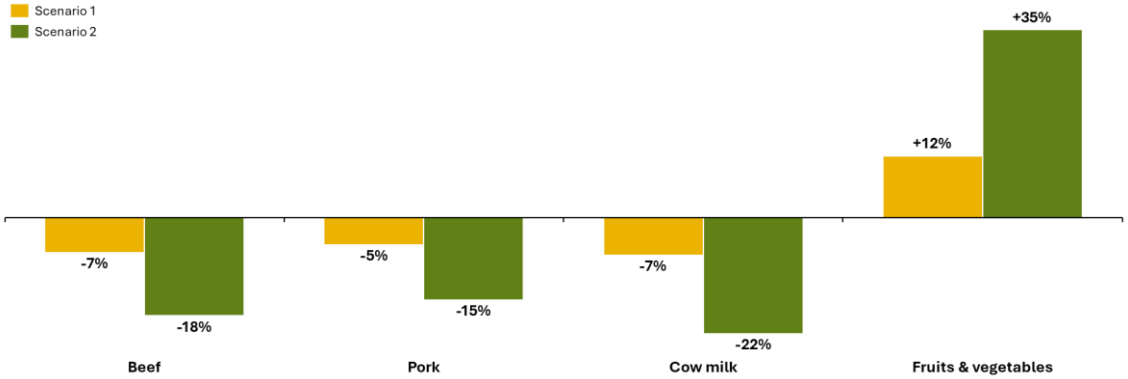
experience production increases, moderated by decreased demand for animal feed (Hristov et al., 2024). The European net trade position for animal-sourced products is expected to improve, due to lower import levels and increased exports of European livestock products, driven by declined domestic demand and lower producer price levels. Increased demand for plant-based products is expected to adversely affect the net trade position for European crop production, with increased imports and lower exports driven by higher domestic demand and higher producer price levels, moderated by reduced animal feed demand. Through international trade, European dietary changes could impact demand, producer prices and production in non-EU countries as well, particularly producer price increases for fruit and vegetables and decreases for animal-sourced products (Drogue et al., 2020; Hristov et al., 2024; Rieger et al., 2023).

Described results on an aggregated European level should arguably only be understood when acknowledging differentiated agricultural production impacts across regions, member states and farms. This could be illustrated by a strong increase in European legume production in both scenarios, with significant variations across regions, driven by among others relative profitability of legume cultivation compared to other farming options. Moreover, scenario modelling patterns indicate a greater flexibility to diversify for smaller than for larger farms. It is suggested that smaller farms are expected to reduce livestock production and increase crop production in general more than larger farms, potentially driven by a higher margin-pressure due to declining livestock producer prices and greater agility driven by a lower cost-base (Hristov et al., 2024).

## 3.3 Impacts on agricultural producer prices

Driven by simulated lower European demand, producer prices are projected to decline for animal-sourced foods in both scenarios, with the largest relative decreases for cow milk (-7.1% to -21.7%), pork (-5.1% to -15.4%), beef (-6.6% to -18.4%). Producer prices are projected to increase for fruits and vegetables (+11.5 to 35.1%) and all of Europe's major crops in both scenarios, although the increase for certain crops such as cereal and soy is moderated by decreased animal feed demand (Rieger et al., 2023). The producer price level increases for minor European arable crops are mainly driven by demand for legumes, that is showing the greatest relative producer price increase across all crops (Hristov et al., 2024).

**Figure 4: European producer price effects from two scenarios on a baseline for beef, pork, milk and fruits & vegetables (%)**




*Source: author's visualizations based on selected CAPRI model output data from Rieger et al. (2023).*

Producer prices are impacted by both the magnitude of the demand changes in both scenarios and the assumed flexibility of agricultural production factors to diversify in line with demand changes. The underlying economic models constrain the flexibility of agricultural production factors to diversify, such as from livestock towards arable farming, acknowledging the complexity of changing farming systems. This assumption leads to supply shortages and surpluses to meet changing simulated demand and results in a greater magnitude of producer price changes. These price simulations could build the case that improving the capacity of farmers to diversify towards plant-based food demand opportunities could both moderate the magnitude of producer price and associated consumer price impacts, while simultaneously increasing the share of farmers benefiting from demand increases for plant-based foods.

***'Expanding the diversification capacity of farmers could potentially minimize the magnitude of producer and consumer price changes, while increasing the share of farmers benefiting from increased plant-based food demand.'***

## 3.4 Impacts on farmers' income

Assessed economic studies simulated farmers' income as gross value added (GVA) plus premiums, which is impacted by the above-described demand, producer price, international trade and agricultural production effects. The assessed studies show similar direction of effects, but without consensus on whether the aggregated European farmers' income is moderately positively or negatively impacted by scenarios with 10%-30% approximation of the EAT-Lancet diet.[2] However, the studies agree that income impacts on a regional, member state and farm level are highly heterogenous (Hristov et al., 2024; Rieger et al., 2023). Although European animal-sourced food production is expected to become more competitive on the global market due to reduced producer price levels, the increased exports are not projected to fully compensate negative income effects from reduced domestic demand and lower producer prices. The reverse is true for income gains driven by fruits, vegetables and nuts production, which are assumed to have a relatively high value added. Regions with projected income losses are mainly regions with a high degree of specialisation in livestock production, especially in the short-term when agricultural production is assumed to be less flexible. An example is Italy which is projected to overall increase its agricultural income by 3.2% to 12.3% driven by higher producer prices for fruits and vegetables, which are offsetting simulated income losses in Italian regions specialised in livestock, such as Lombardia (-13.8 to 28.5%) (Rieger et al., 2023).

Results at farm-level show a trend line indicating that smaller farms are expected to face relatively lower average losses, while the segments of lower economic size farmers could have more positive income changes. Farm type drives roughly 60% of the variations in farm income changes in the used CAPRI model simulation (Hristov et al., 2024). Farmers' income simulations from dietary changes highlight the need to acknowledge the heterogeneity of European farmers behind the aggregated European or member state level results. Furthermore, these farmer income simulations need to be further refined and for example do not (fully) include agricultural inputs (such as fertilizers), yield gains (biodiversity improvements) and cost avoidance (climate change resilience and poverty in agricultural communities). Moreover, it should be acknowledged that besides farmers' income, other indicators should be assessed as well, such as farm profitability, the quality and type of farming work, wages of farm workers and farmers' well-being.

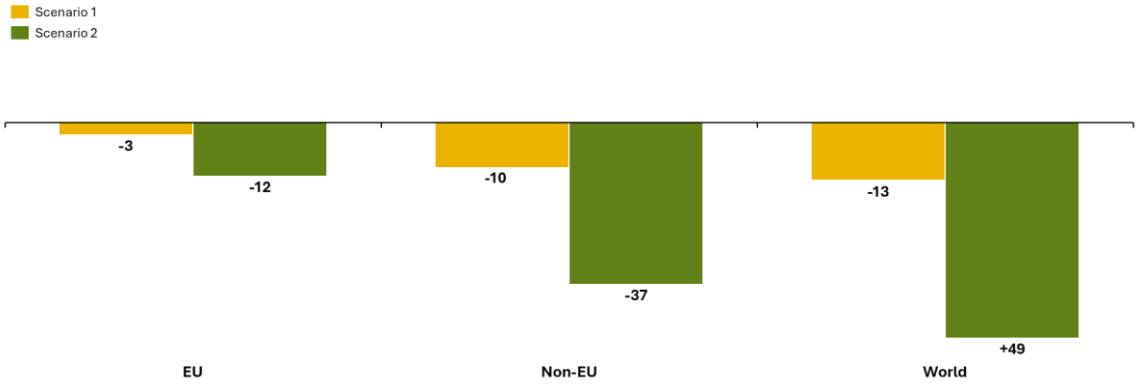
### Potential impact on GHG emissions

The two simulated dietary scenarios reduce global GHG emissions by an estimated -13.1Mt to -48.6Mt in $CO_2$ equivalents in 2030. These emission

[2] The assessed studies are using the same CAPRI model, but different versions, base and target years and variations in product mapping of CAPRI and EAT-Lancet categories.

reductions are predominantly driven by reduced livestock production, with beef in particular, that offsets higher GHG emissions projections from increased plant-based food production. The simulated scenario results suggest that GHG emission reductions from European dietary change is predominantly driven by non-EU GHG reductions, and just to a limited extent by European GHG reductions (-2.8Mt to 12.1Mt $CO_2e$). This is driven by increased carbon-intensive exports of animal-sourced foods and lower carbon-intensive plant-based imports from non-EU countries, and therefore the emission reductions are partly 'exported' abroad (Rieger et al., 2023). However, the impact from trade on emissions needs more nuance, for example driven by the assumption that European animal-sourced production is on average less carbon-intensive per kg of output compared to production in some non-EU regions (European Commission, 2021).

**Figure 5: Impact from two scenarios on European, non-European and worldwide GHG emissions, compared to baseline GHG emissions (in Mt of $CO_2e$)**




*Source: visualizations based on data from Rieger et al. (2023).*

## 3.5 Limitations and key opportunities for next studies

The above-discussed studies have shown how economic modelling of dietary change scenarios could provide insights into socio-economic impacts on farmers and the agricultural sector from protein diversification (Hristov et al., 2024; Geibel et al, 2021; Rieger et al., 2023). Further research should focus on including (indirect) effects from environmental impacts (e.g., climate change, biodiversity and environmental pollution), the specific impact on rural communities and the role of alternative proteins (e.g., plant-based meat, microbial fermentation and cultivated meat). Relevant policy options to include in future economic models include re-directing CAP funding towards compensating switching costs for farmers and agrifood value chains and supporting protein crops, which will be further discussed in next chapters.

# 4. IMPLICATIONS OF PROTEIN DIVERSIFICATION FOR EUROPEAN FARMERS

As shown in the previous chapter, protein diversification could provide both economic opportunities and risks to European farmers and the wider agricultural sector. This could be amplified by 'shock effects' when European agricultural production is unable to diversify in line with demand changes. The type and magnitude of opportunities and risks from protein diversification are likely to be differentiated across regions, agricultural systems and arguably from farm to farm (Hristov et al., 2024; Rieger et al., 2023).

## 4.1 Economic opportunities and risks for European farmers

Protein diversification could be an opportunity for arable farmers to expand their production and increase producer price levels, especially when already cultivating fruits, vegetables or legumes. Nevertheless, reduced livestock demand could pose a risk to European livestock farmers and workers in animal-sourced value chains, especially for rural communities with livestock as main source of income and with unsuitable topographic conditions for crop farming, or for capital-intensive supply chains that rely on large volumes of animal-sourced foods (Craft and Pitt, 2023; McGregor and Houston, 2017). This might not be problematic given that protein diversification is not replacing livestock, but shock effects on production and prices could pose a risk to farmers' income. There could be opportunities beyond arable and livestock farming as well, such as the opportunity to valorise agricultural side streams as fermentable sugar feedstock for microbial fermentation or other bio-economy purposes (Raak et al., 2023). A multitude of indirect opportunities and risks are at play for farmers, such as risk avoidance from negative yield impacts from soil degradation or droughts (Rieger et al., 2023).

## 4.2 Improving agricultural production diversification capacity

The potential economic impact of protein diversification on European farmers is not predetermined but will strongly depend on the capacity of farmers to diversify towards plant-based or alternative protein opportunities. If farmers diversify their business models in line with demand changes, potential losses from lower animal-sourced demand can be offset by higher production and producer prices for crop cultivation. Empowering farmers to capture plant-based or alternative protein opportunities could therefore avoid socio-economic losses among European livestock farmers and a high plant-based food trade deficit (Hristov et al., 2024; Rieger et al., 2023). Since farmers are unlikely to diversify in anticipation of dietary change, it is arguably important to prepare farmers to diversify by lowering structural barriers that may hinder them from diversifying in the future. This

preparation should arguably focus on how farmers can diversify their cropping systems or switch to crop cultivation, rather than on whether they should produce animal-sourced foods (Craft and Pitt, 2023).

## 4.3 The complexity of and barriers towards protein diversification for farmers

Diversifying from livestock to mixed or arable farming, or even switching between crops, could be a major and complex change for farmers and could involve re-directing of land, labour and capital (Sutherland et al., 2012). Moreover, farmers can be locked-in by 'path dependency' where entrenched skills, investments, and equipment hinder the change of established practices, compounded by knowledge and cultural lock-ins. Given the complexity of diversification, the willingness of livestock farmers to diversify is likely to be reduced by relatively high producer prices for animal-sourced foods, stable demand from relatively well-developed value chains for some types of livestock, combined with CAP support. Trigger events, whether positive or negative, can prompt farmers to reconsider their farming systems (Sutherland et al., 2012).

Recent research among Welsh farmers indicates that the diversification capacity of livestock farmers could be hindered by (perceptions of) financial and farm environment inflexibility, such as (perceived) unsuitable climate, topographic or farm-specific characteristics to cultivate crops. Perceptions can be driven by behavioural and socio-cultural influences as well, such as scepticism regarding the magnitude of dietary change, polarized views on plant-based diets, the importance of social status in rural areas and the confidence that demand for meat from Welsh extensive livestock will remain (Craft and Pitt, 2023). Insights from another study suggests that the diversification capacity of farmers is among others driven by the farmers' perception and management of risks, reorganization skills, financial and psychological ability to change and the interest and willingness to diversify (Marshall et al., 2014). Despite its significance, there is surprisingly limited research that considers the perspectives and needs of European farmers regarding the agricultural production implications of dietary change, making it a crucial area for further study (Craft and Pitt, 2023; Lonkila and Kaljonen, 2021; McGregor and Houston, 2017).

## 4.4 The opportunity of protein-crops for farmers and ecosystems

To further explore barriers for farmers to diversify towards plant-based demand opportunities the subsequent chapters will focus on barriers towards profitable cultivation of legume crops by European farmers. Legumes are a key part of the EAT-Lancet dietary recommendations for a healthy and sustainable diet (Willet et al., 2019). As described in chapter 3, legumes are projected to have the greatest relative production growth and producer price growth in both simulated dietary

shift scenarios (Hristov et al., 2024; Rieger et al., 2023). Although being hypothetical, the simulated demand scenarios for the year 2030 resulted in an estimated additional legume crop revenue opportunity of €0.4B – €1.3B for European farmers, with the large bandwidth driven by uncertainty about European production versus imports (Rieger et al., 2023). An additional opportunity for European legume crops is to serve as ingredient in plant-based meat products that are forecasted to grow significantly towards 2030, but were omitted from the estimation because of uncertainty of these forecasts (Verkuijl et al., 2023).

Adding legumes to crop rotations could unlock additional benefits to farmers, such as reduced fertilizer and agrochemicals usage due to the ability of legume plants to fix atmospheric nitrogen, improved health of subsequent crops and the soil and break cycles of pest and crop diseases (Stagnari et al., 2017; Brannan et al., 2023; Preissel et al., 2015). These benefits could provide profitability opportunities to farmers, including reduced input costs, increased yields and decreased financial risks stemming from soil degradation and environmental pollution (Barman et al., 2022). From an ecosystem perspective, key benefits from crop diversification are increasingly documented in scientific literature and include carbon sequestration (climate change mitigation), enhancing resilience to climate change effects, reduced pesticide use, improved soil fertility and biodiversity (Magrini et al., 2016; Meynard et al., 2018; Moraine et al., 2016).

# 5. BARRIERS FOR FARMERS TO DIVERSIFY TO PROFITABLE LEGUME CULTIVATION

This chapter explores barriers for European farmers to diversify towards legume cultivation for food purposes, including through multiple- or intercropping. Protein crops such as legumes are considered minor crops in Europe, with a marginal share of ~3% of total European production for soybeans and dry pulses. Although the domestic production of dry pulses increased by ~42% over the last decade, predominantly driven by feed purposes, it remains a marginal ~2% share of total EU plant-based protein production. Legumes are one of the crops for which Europe is not nearly self-sufficient, mainly driven by feed demand for European livestock (European Commission, 2024).

## 5.1 Lock-in effect by major European crops

Evidence suggests that a dominant majority of a small number of crops causes a lock-in effect that challenges the production of minor crops, including legume crops. This lock-in is caused by a comparative advantage stemming from economic specialization into major crops, driven by among others cost-efficiency, technological, cognitive and policy advantages, that result in among others economies of scale (Revoyron et al., 2022; Zander et al., 2016). Crop diversification towards minor crops, such as protein crops, is required in the EU to break the dominance of simplified cropping practices, based on high-input monocultures, a low diversity of crops (~75% of European arable land cultivated with just 10 species) grown in short rotations (~68% of EU arable land grown with 2-4 crop rotations) (Ballot et al., 2023; Eurostat, 2020; European Commission DG ENV., 2020). The dominance of these simplified cropping practices results in environmental degradation (Ballot et al., 2023; Messéan et al., 2021).

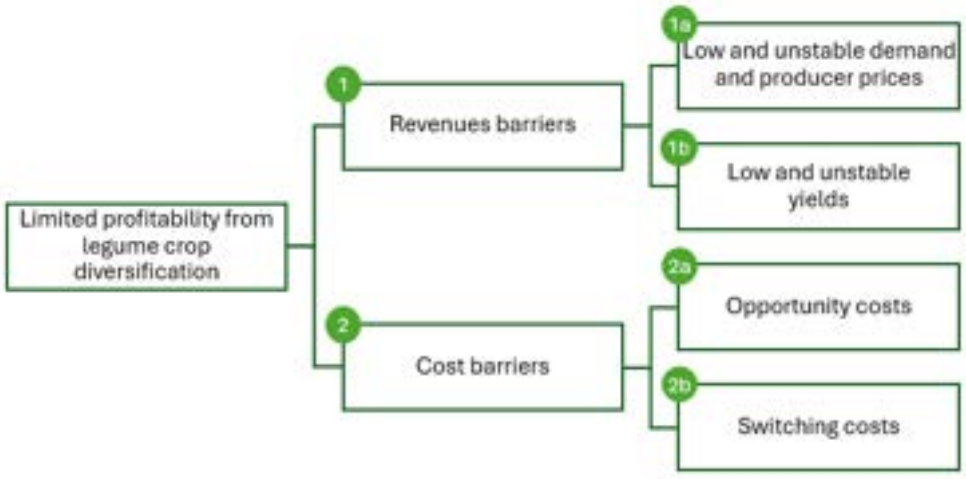
## 5.2 European efforts to overcome a lock-in

Over the last decade, research efforts have been on a European and Member State level to overcome the lock-in of major European crops and to enable cultivation of minor protein-crops in Europe. European policymakers invested into crop diversification research programs running over 2017-2027, with a majority invested into a joint Crop Diversification Cluster including Horizon 2020 studies focussed on diversification crops including legumes (Crop Diversification Cluster, 2019). Furthermore, initial progress has been made on establishing value chains and cooperations (e.g., Donau Soja) and increasing agricultural production (e.g., as ingredient for plant-based dairy).

## 5.3 Barriers to farmers for profitable protein crop cultivation

The barriers that minor crops such as legumes are experiencing in Europe against major crops is increasingly documented in science (Brannan et al., 2023; Degieter et al., 2023; Ferreira et al., 2021; Magrini et al., 2018). Academic research on European legume cultivation indicates at least four key profitability barriers for European farmers to diversify towards protein-crops. The barriers and their relevance are not similar for all farmers, since barriers can be context-specific, inter-connected and occurring at multiple levels along supply chains (Antier and Baret, 2025).

**Figure 7: Profitability barriers for farmers to diversify to legume cultivation (non-exhaustive)**




*Source: author's own compilation*

### 1. Revenue barriers

a) **Demand & producer prices** - Legumes for European food consumption seem to be susceptible to demand fluctuations, mainly due to changing consumer behaviour over the last decade and relatively immature value chains (e.g., plant-based meat alternatives) (Brannan et al., 2023; Magrini et al., 2018). Food demand changes directly impact producer prices for legumes, for example when a farmer needs to sell it as animal feed.

b) **Yield** - European legume production has in general relatively low and unstable yields compared to major EU crop yields, due to both biotic (e.g., pests) and abiotic (e.g., droughts, heavy rainfall) factors. Genetic progress of legume yields has been limited, especially compared to major EU crops, resulting from relatively low historical public and private investments in legume crop research and breeding programs, and a relatively low level of legume crop management experience among European farmers (Brannan et al., 2023; Zander et al., 2016; Watson et al., 2017).

**2. Cost barriers**

a) **Switching costs** - Crop diversification could lead to switching costs for farmers due to required up-front farm-level and downstream efforts and investments to adapt farming systems and wider transportation, storage and processing that are currently specialized in major crops. Farmers need to adapt themselves to new crop planting, management, harvesting, processing and storing practices and technologies, including an understanding of interactions with other crops on their fields. Besides, legumes are lacking the wider value chain economies of scale advantages for storage, transportation and processing activities that were tuned to for example cereals (Ferreira et al., 2021; Magrini et al., 2018; Zander et al., 2016).

b) **Opportunity costs** - Crop diversification can be hindered by opportunity costs compared to other farming options providing higher profits, yet providing less ecosystem services. For example, low-cost competition from imported Brazilian soy puts pressure on domestic European soy production, despite the sustainability benefits of domestically cultivated soy. Government support is a key driver for the current European agricultural production, but historically lacked incentives for crop diversification (Magrini et al., 2018; Zander et al., 2016). Over the last decade, the EU has revived their interest in crop diversification and funded at least six research programs bundled in a EU Crop Diversification Cluster (EU, 2020).

## 5.4 Barriers beyond profit and loss drivers

Besides profitability drivers, barriers to crop diversification can stem from multiple other factors as well such as the ability, capacity and willingness of farmers to diversify. Furthermore, the farmer's perception of the barriers and knowledge of legume cultivation is essential as well. Studies that surveyed European farmers emphasized that despite context-specific differences, a farmers' risk appetite, sustainability objectives and legume crop knowledge are determining factors in whether and to what extent farmers diversify their production (Degieter et al., 2023; Suvanto et al., 2020; Zimmer et al., 2015; Carof et al., 2019). An example of a lower profitability perception of legume production is the case if potential fertilizer cost-reductions and yield improvements of subsequent crops are omitted from profitability calculations (Brannan et al., 2023; Nilsson et al., 2022).

# 6. LEGUME DIVERSIFICATION STORIES FROM EUROPEAN FARMERS

Passages were selected from interviews with farmers about their firsthand experiences with barriers to legume cultivation and their views on lowering these barriers.

**Box 1: Noortje's perspective on legume diversification opportunities for dairy farmers**

**Noortje Miedema-Krol** runs a mixed dairy and arable farm with her husband Nico in the Dutch province of Noord-Brabant. After taking over the dairy farm from her father in 2018, she decided to diversify by incorporating cereals, field beans, and chickpeas, alongside initiatives aimed at promoting biodiversity.

***"We need to rebalance animal-sourced and plant-based foods in our food system, while making dairy farming more sustainable"***

Noortje has firsthand experience in overcoming barriers to profitable legume crop diversification. When sharing her profitability calculations, she explained that cultivating field beans can be challenging as a dairy farmer, for example, due to handling potential yield impacts of pests and diseases. However, she noted that "*the numbers started to add up after our decision to collaborate with an experienced partner and received support from CAP eco-schemes.*" Speaking from her own pioneering experiences, she emphasized that "*as farmers, we need to increase our knowledge of cultivating legumes, organize ourselves into cooperatives, and be better supported by subsidies, fairly priced seeds, and robust species.*" Despite this, she sees opportunity costs from imported soy as a major profitability barrier: "*As a dairy farmer, you compare the input costs of under-priced imported soy with the costs, efforts, and risks of cultivating your own concentrate feed*" she explains. She adds, "*We can't reverse decades of underinvestment in European legume production overnight, but we can choose to support initiatives that help farmers diversify towards sustainable and balanced food production".*

### Box 2: Benedikt's call for a long-term vision to overcome structural barriers

Building on a 700-year family legacy, **Benedikt Sprenger** manages a mixed arable, vegetable, and pig farm in the heart of Westphalia. He learned that his family farm had evolved over generations, which he contributed to as well by growing new crops like edamame, faba beans, and soybeans.

***"We need to come together and overcome polarization between plant-based and animal-sourced food"***

"*Climate change poses a threat to every farmer*" says Benedikt and adds: "*and that's why we need to work together to diversify farming towards a more sustainable food system.*" Benedikt stresses the need for a long-term vision: "*We need plant breeding and education of farmers, but this takes time. The same is true for commitments from supply chains to farmers growing legumes.*" He is cautious about comparing legumes to major crops: "*It's hard to compare legumes with cereals, since the best land is already used for cereals, and weed control solutions are limited for legumes. Moreover, we must consider indirect benefits from legumes as well."* He believes that a solution should start with demand for legumes in European supermarkets, grown by European farmers who can fairly compete with cheap soy imports.

### Box 3: Ádám's appeal to create local food demand and lower opportunity costs for legumes

**Ádám Lamberti** and his family members are running their farm for over 2 decades in the steppe and forest region of Kisalföld. He cultivates both extensive organic cropland and bio-intensive vegetable production in open fields and an unheated greenhouse. He aims to stabilize his income by planting legumes alongside cereals to diversify soil usage and to enrich the soil's nitrogen content.

***"Demand for legumes is currently volatile, but I believe growing legumes could potentially be more profitable than cereals"***

Ádám stresses the importance of legume demand: "*we need a stable local market for legume food products, for example by integrating them with public catering*" and explains how demand connects to other challenges: **"***If we would have a stable local market it would lead to the emergence of a stable seed market as well. Currently, seed procurement is more difficult for legumes because of a smaller selection, especially compared to cereals."* Subsidy requirements are a key barrier for Ádám, as he explains: *"I can't access additional subsidies due to high required legume yields, especially because of a lack of distinction between organic and conventional farming yields for coupled subsidies, and increasingly unpredictable weather conditions"*

### Box 4: Zoltán's view for a broad consortium to overcome barriers

**Zoltán Szabó** runs his farm for over 11 years on the Southern Great Plain in Hungary where he has been practicing regenerative farming since 2017. He dedicated 3 years to researching legumes and concluded that it is essential for soil life to replenish nitrogen naturally through the fixation of legumes.

***"Growing legumes for food consumption can drive great economic benefits"***

Zoltán shared his view on switching costs: *"having knowledge is not enough to successfully cultivate legumes. Farmers need to gain practical experience to generate good yields."* Besides, he stressed the importance of plant-protection to achieve sufficient yields: *"There are no approved plant protection products (herbicides) available for alternative legumes, such as cowpea."*. He experienced a lack of demand as well: *"The biggest issue is the lack of a market. There are no processors willing to buy, package, process, and sell these products. Therefore, there is a lack of available seed stock."* He shared his view on a required solution: *"A consortium should be established involving a research institute, a farmers' organization, a processing industry and marketing company. This could enable a solution to these issues."*

### Box 5: Alfred's argument for accelerating on-farm trials and data collation

**Alfred Grand** has a 90-hectare arable field research and demonstration farm focusing on soil-health, agroforestry and market gardening. On his farm close to Vienna, he grows crop rotations of lentils, soybeans, hemp and many other crops, using low-till methods to maintain and improve his soil. Lentils are even seeded directly into a rye cover crop using the roller-crimper organic no-till method.

***"We don't have 70 years to create profitable legume business models, so we need to learn and scale fast"***

Alfred speaks from his vast experience as a farmer and researcher when stating: "*Volatile prices are a significant barrier for legumes, such as recent sharply declining prices for soybeans and lentils. Besides strengthening European legume food demand, we should explore shortening supply chains with farmers directly delivering to food processors or retailers. We should explore carbon credits for cover crops as well, also to reward not tilling the soil.*" To improve legume yields Alfred adds: "*We could overcome the lack of data and research on generative farming methods, by incentivizing on-farm trials and data collection through the CAP and use that to share knowledge with farmers.*" In his experience, indirect benefits, such as reduced fertilizer costs for legume cultivation, are often omitted from profitability calculations. Meanwhile, switching costs for farm-equipment are sometimes overestimated, for example when diversifying from cereals.

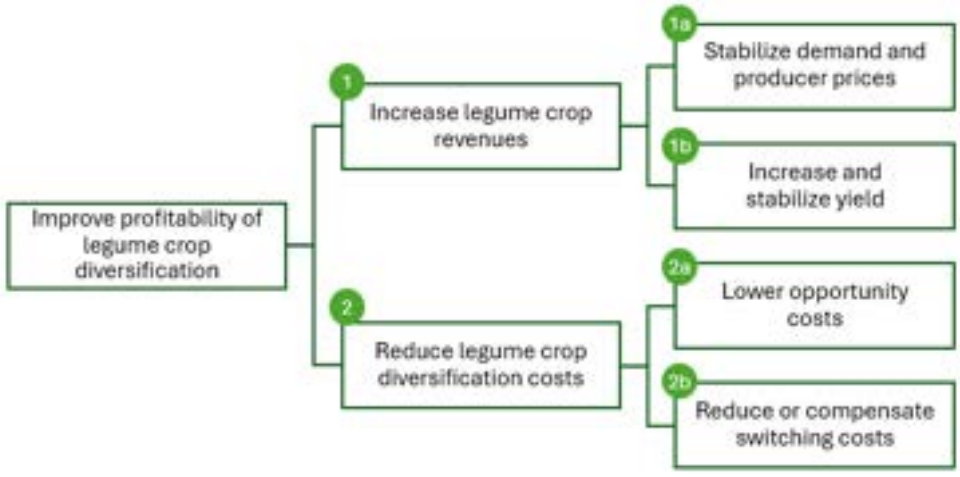
# 7. LOWERING BARRIERS FOR EUROPEAN FARMERS TO CAPTURE LEGUME OPPORTUNITIES

Creating profitable business models to cultivate legume crops could enable European farmers to diversify towards new opportunities while generating wider ecosystem benefits across Europe. This approach could support and encourage farmers who are willing to cultivate protein crops, without forcing farmers to diversify their business. By lowering profitability barriers for legume cultivation, Europe's agricultural sector could enhance its resilience to dietary change, by preparing itself to seize protein crop opportunities if dietary patterns shift accordingly.

## 7.1 Identification of options to lower profitability barriers for farmers

This report briefly lists options to lower profitability barriers, based on a synthesis of interviews with European farmers, a recent ESAD brief on crop diversification (Antier and Baret, 2025) and academic literature. Options to increase profitability might need tailoring to regions, agricultural systems and farm types. The listed options to lower barriers should, therefore, be regarded as a starting point to engage in structured dialogues with European farmers to validate and further refine them.

***Figure 7: profitability drivers for farmers to diversify to legume cultivation (non-exhaustive)***




*Source: author's own compilation*

## 7.2 Profitability drivers for farmers to diversify towards legume crop cultivation

### 1. Increase revenues by raising legume demand, producer prices and yields

a) **Increasing and stabilizing demand** for legume crops as food ingredient could help farmers to secure sales of their legume crops and to benefit from generally higher crop prices for food compared to animal feed (Sepngang et al., 2019). Key levers to increase and stabilize legumes demand include the following:

- Building **European value chain partnerships** from farmers to retailers to coordinate cultivation of legumes that fit food processing and market requirements best. These partnerships should decrease and share risks around demand uncertainty and provide farmers with better knowledge on market trends (Antier and Baret, 2025; Dib et al., 2024).
- Adopting **suitable contractual arrangements** for farmers that secure their risk-taking and investing, such as addressing risk-sharing and flexibility around issues related to variability in production, duration and a fair sharing of added value between actors (Dib et al., 2024).
- **Incentivization of plant-based food consumption in food environments** where Europeans buy and consume food, through improving the availability, affordability, convenience, and desirability of plant-based foods (Van Hoeven et al., 2024; Herforth and Ahmed, 2015). Although a multitude of relevant policy instruments exists, it is widely recognized that market-based instruments (such as taxes and subsidies) and regulatory instruments (such as public procurement rules, school meal programs) are effective to influence food consumption behaviour. A recent study by Springman et al. (2024) suggests that reforming current value-added tax (VAT) rates by increasing VAT rates on meat and dairy and lowering rates on fruits and vegetables can have a positive health, environmental and economic impacts in most European countries. Furthermore, evidence suggests that policy mix approaches are more effective than stand-alone measures, such as combining food taxes with information-based instruments such as food labelling and educational campaigns (Temme et al., 2020; Tadic, 2024; Ammann, 2023).

b) **Increasing and stabilizing legume yields** generates a volume multiplier per hectare to farmers and could simultaneously help ramping-up high-protein crop production without increasing land-uptake. Stabilizing yield is needed to de-risk volume volatility for farmers, while yield increases are needed to close European legume yield gaps and improve competitiveness towards European major crops such as cereals and legume imports from

abroad (Van Loon et al., 2023; Zander et al., 2016). An important nuance could be made that an over-focus on yields is part of the lock-in on major crops, while the key question is to find revenue streams that do not hinder environmental benefits, such as increased combined yields from mixed crops or increased pest resilience of crops (Vanloqueren et al., 2009). Key levers to increase and stabilize legume yields include the following:

- Accelerate **legume breeding programs** to improve an optimal balance of legume plant traits regarding improving crop yields, increasing resilience to pest, diseases and weed, adapting to changing European climate conditions and catering to market and food processing requirements. Breeding programs should involve breeding, cultivar testing and cultivar information systems and focused on actionable insights for farmers (EU CAP Network, 2024; Antier and Baret, 2025).
- Execute EU-wide, long-term, **legume farming experiments**, collect standardized results centrally and leverage subsequent learnings to support farmers. The applicability of obtained learnings could be increased by strategically selecting experiments based on their geographical location, farming practices, supply chain and institutional context.
- Organize legume cultivation **training and knowledge sharing** among European farmers wanting to diversify. Interviews suggest that training sessions should be action-oriented for both arable and livestock farmers and should be flexible towards farmers' sometimes unpredictable commitments to work on their fields. Furthermore, interactive digital tooling such as AI could be used to lower barriers for farmers to accelerate their knowledge.
- Increased valorisation of minor crop **side-streams** can provide additional revenue streams, that can be around 60%–75% of the legume raw material (Ratnayake et al., 2021). These side-streams can be used for animal feed or often higher-valued food purposes, such as serving as feedstock for microbial fermentation processes.

### 2. Reduce or compensate switching and opportunity costs

a) **Reduce or compensate switching costs** stemming from up-front investments for farmers to diversify towards minor protein-crop cultivation. Switching costs can stem from tangible matters such as new or adjusted equipment and storage rooms, but also to (time-) investments in obtaining new knowledge and farm practices.

- Fund research and provide advice into **adapted or shared on-farm equipment** catering to diversified crops or adapting crop cultivation systems to existing machinery (Antier and Baret, 2025).

- Improve farmers' **access to finance** through an EU Just Transition Fund, de-risk private finance, such as through adapting bank lending frameworks to sustainable practices and increased EIB investments in sustainable protein diversification
- **Increase CAP support (EAFRD)** to embed crop diversification in Measures for environment, climate and animal welfare (ENVCLIM) and in the measures supporting investments and knowledge exchange, including machinery and knowledge sharing (Antier and Baret, 2025). This should among others include the support for farmers during the experimentation phase when they gain experience and innovate with diversification crops.

b) **Reduce opportunity costs** compared to farming practices without legume crop diversification. This could be seen as a compensation for the risk that a farmer takes to provide ecosystem services that benefit society.
   - Better **shield crops with relatively high ecosystem services** from lower-cost competition with less ecosystem benefits. Multiple options need to be carefully considered, from carbon-pricing (agricultural ETS/C-BAM) to adopting stricter deforestation laws (EUDR).
   - Translate current Horizon research projects into **best practices and interactive tooling** (such as AI) to estimate indirect cost reduction potential from crop diversification (e.g., increased yields in subsequent rotations, reduced fertilizer usage costs).
   - Increase financial support for crop diversification by **re-directing area-based basic payments to eco-schemes** enhancing crop diversification and strengthening conditionality requirements.

# 8. POLICY RECOMMENDATIONS

Empowering European farmers to drive and benefit from protein diversification requires long-term commitment and decisive action from policymakers, the food industry, the agricultural sector and consumers. Insights from this report translate into five key policy recommendations, which are complementary to other initiatives aimed at strengthening the role of farmers in Europe.

**Figure 8: Five policy recommendations to empower European farmers to drive and benefit from protein diversification (non-exhaustive)**


### 1. Develop an EU protein diversification strategy

An updated and more holistic EU protein diversification strategy, including food and feed, is required with clearly articulated impact targets, including economic benefits for farmers, aligned with adjacent policy areas (e.g., bio-economy). This strategy should include, at a minimum:

- An EU **protein diversification target and roadmap**, adapted into member-state-specific culinary and agricultural action plans (such as in Denmark).
- **Aligned protein diversification strategy with adjacent EU strategies** to maximize its impact, such as climate 2040 targets, bio-act, zoonotic disease prevention, animal welfare and generational renewal initiatives for farmers.
- **Supporting research into potential socio-economic impact on farmers** from protein diversification through engaging in structured dialogues with farmers and by conducting agro-economic modelling studies (e.g., CAPRI) to compare socio-economic and environmental impact from policy options (see chapter 3).

### 2. De-risk and reward crop diversification initiatives by farmers

Farmers and their rural communities should receive better support for risks associated with crop diversification, while ecosystem benefits should be effectively rewarded.

- **Use CAP instruments to compensate and reward farmers for their risk-taking and ecosystem contributions,** by overall strengthening conditionality requirements, increasing support and ambition for crop diversification in eco-schemes, embedding crop diversification in Measures for

Environment, Climate & Animal Welfare and supporting investments and knowledge exchange.

- **Improve farmers' access to finance** through an **EU just transition funding mechanism** for Agriculture, de-risked private finance and increased EIB investments in protein diversification. An EU just transition funding mechanism for Agriculture could provide targeted financial support for crop diversification or adopting sustainable practices. Such funding could strengthen vulnerable farmers and rural communities and could encourage private investment to unlock additional financial resources (Baldock et al., 2025).
- **Better shield crops with ecosystem benefits from unsustainable lower-cost competition**, with multiple options to be carefully considered, from carbon-pricing (agricultural ETS/C-BAM) to adopting stricter deforestation laws (EUDR).

### 3. Support diversified value chains with a strong position for European farmers

Enable the creation of sustainable and competitive protein crop value chains with a high level of collaboration across the value chain and a strong position for farmers.

- Create steady demand for sustainable and healthy (local) protein crops to cover the experimentation phase of new diversified value chains through **public procurement and public canteens**, together with retailers and foodservice players.
- Incentivize **collaboration from farm to fork across value chains**, aimed at overcoming barriers for farmers, processors and retailers, and accelerate learnings.
- Adopt **suitable contractual arrangements and fair pricing** for farmers that secure their risk-taking, such as risk-sharing and flexibility around issues related to variability in production, duration and a fair sharing of added value (Dib et al., 2024).

### 4. Co-create a European plant-based innovation cluster

Co-create an EU innovation cluster that effectively unites public, industry, research, and civil society stakeholders to accelerate plant-based food innovation

- Initiate **public-private plant-based food innovation and farming experiments** to overcome barriers and reduce time to market for innovations.
- Accelerate **multi-disciplinary research programs** towards lowering barriers for farmers to diversify towards (partial) plant-based food production. A key priority should be **protein-plant breeding programs** to improve an optimal balance of crop yields per region, resilience to pest, diseases and weeds, adaptation to changing climate conditions and catering to market

and food processing requirements. Other priorities include **adaptation of agricultural equipment** and **valorisation of agricultural side-streams** (e.g., as input for microbial fermentation).
- Organize **training and knowledge sharing** among farmers willing to diversify to protein crops and leverage interactive digital tooling such as AI.

### 5. Make sustainable and healthy foods the easy option for European consumers

Collective action is required to create an equitable playing field between animal-sourced and plant-based foods in food environments, tailored in action plans by Member States.

- Organize **round tables to set protein diversification targets** with European food environment players such as retailers, food processors and civil society actors, following the example from recent protein diversification pledges by European retailers (Ahold Delhaize, 2025; Lidl, 2025).
- **Monitor protein diversification progress** across Member States, with a common and transparent set of metrics, and share results and learnings frequently.
- Enable a **more equitable level playing field between plant-based and animal-sourced foods** in European food environments by reviewing the policy-mix that is currently shaping plant-based and animal-sourced sales (e.g., VAT levels, CAP).

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# ANNEX 1: ASSESSMENT OF KEY EUROPEAN PROTEIN DIVERSIFICATION IMPACT AREAS

### Environmental: mitigate and build resilience towards a triple planetary crisis

- **Climate change** - The European agrifood system is both significantly effected and a major driver of climate change, with a 30% share of total European GHG emissions (FAO, 2022). The European livestock sector is estimated to emit a share of 10% of total EU GHG emissions, including for feed inputs and excluding for land-use change and transport, processing and packaging (Lesschen et al., 2013). Livestock emissions are mainly driven by enteric fermentation, manure management and fertilizer usage for feed production (Lesschen et al., 2011). Reducing the share of carbon-intensive animal-sourced proteins in favour of plant-based foods could reduce livestock's GHG emissions (Frank et al., 2019; Willet et al., 2019; Poore and Nemecek, 2018). Evidence suggest that this could positively affect other impact areas as well, since current and forecasted climate change effects -such as rising temperatures and extreme weather- pose a threat to biodiversity, food and water security (IPCC, 2023).
- **Pollution** – European agriculture is the major source of European air pollution and its adverse health impacts (Himics et al., 2022). Ammonia emissions, 66% of which originate from livestock farming, represent the largest air pollution challenge within the EU (EEAa, 2024). A recent study estimated that an average flexitarian diet could reduce agricultural ammonia emissions in the EU by 33% (Himics et al., 2022). European agriculture is also the most significant driver of surface and groundwater pollution, and indirectly impacts water and aquatic ecosystems through air pollution by nutrients and pesticides (EEAb, 2024). Although further research is required regarding soil pollution and associated impacts on European ecosystems, evidence suggests that manure pollutants from intensive livestock generate levels of copper and zinc that are above safety standards (EEA, 2023).
- **Biodiversity** – The intensification of European agriculture is the most frequently reported driver of loss of habitat and species and drives 50% of biodiversity loss caused by pollution. Unsustainable agricultural practices, climate change, agricultural pollution land-use changes are documented among the key factors of a deterioration of European biodiversity (EEA, 2020). Besides its role in causing biodiversity loss, the European agricultural production and the livelihoods of farmers is significantly exposed to risks of biodiversity loss, such as yield and income loss due to soil and water erosion and declines in crop pollination (EEA, 2024).

### Planetary resources: enhance planetary resource-efficiency for global and European food security

- **Land-use (change) -** Roughly half of global and European habitable land is currently dedicated to agriculture, while land-usage changes in favour of livestock and feed production are the major driver of deforestation (Eurostat, Verkuijl et al., 2023). An increasingly documented root cause is the differentiated land-use footprints of farming systems, which are typically relatively inefficient for ruminants like cattle and sheep (including for feedstock) and more efficient for vegetables and nuts. This is highlighted by evidence indicating that global animal-based food production supplies roughly 37% of the proteins for human food consumption, but occupies a grand majority of around 77% of agricultural land (Verkuijl et al., 2023). Protein diversification provides the opportunity, through a shift from relative land-use intensive animal-sourced towards lower land-use plant-based foods, to reduce agricultural land-uptake and free up land for other purposes such as reforestation (Poore and Nemecek, 2018; Willet et al., 2019).
- **Fresh water use -** Europe's critical water resources are increasingly under pressure, with agricultural activities documented as a primary cause. The agricultural sector is estimated to account for approximately one-third of total EU water usage, drives water quality degradation through fertilizer and pesticide runoff, and exerts significant ecological pressure on Europe's marine ecosystems (EEA, 2024; EEA, 2020). Although water footprints from food production are highly variable across farming practices, abiotic conditions and regions, protein diversification could relieve pressure on water resources by shifting from relatively high-water intensive animal-based food (including animal feed production) towards more water-efficient plant-based foods (Poore and Nemecek, 2018).
- **Circularity** – An estimated 153.5 million tonnes, equivalent to 20% of the EU food production, is wasted on a yearly basis. Halving European agrifood waste could already save ~4.7 million hectares of agricultural land on a yearly basis (EEA, 2022). Enhancing circularity in agrifood systems entails predominantly minimizing waste, recycling in the most sustainable manner, reducing over-consumption and only feeding human inedible nutrients to livestock animals (Van Zanten et al., 2023). Recent scientific research that combines protein diversification with circularity suggests that livestock production might still play a vital role in a fully circular European agrifood system as a recycler of human inedible proteins, but that it needs to be reduced substantially (Simon et al., 2024).

### Health: increase the share of healthy and affordable foods and avoid diseases

- **Nutritional health** - The global agrifood system generates sufficient proteins to feed the current world population. However, unequal distribution and access to nutritious and healthy foods create a paradoxical situation with both malnutrition and obesity, leading to severe European and global health impacts (Verkuijl et al.,

2023). Globally, an estimated 2.3 billion people face moderate or severe food security, including 864 million people experiencing severe food insecure with grave health risks (FAO, 2024). This paradox emerges in the EU as well, with an estimated 8.3% of the population unable to afford a proper meal and 50.6% considered overweight (Eurostat, 2023; Eurostat, 2024).

- **Non-communicable diseases** – Reducing European over-consumption of red and processed meat can be associated with lower risks for obesity and diseases such as cardiovascular diseases, cancers and type 2 diabetes. Protein diversification could reduce indirect health impacts as well, such as through reducing GHG emissions, air and water pollution (Swinburn et al., 2019).
- **Zoonotic diseases** – Reducing the share of intensive livestock production systems could directly and indirectly lower the risk of zoonotic disease transmission, such as influenza, HIV/AIDS and the COVID-19 pandemic (Otte et al., 2021; Wegner 2022).
- **Anti-microbial resistance** – Reducing antibiotics use in animal-based food production can be linked to lower antimicrobial resistance risks. Antibiotics are currently essential for public health, while widespread antimicrobial resistance could have severe and far-reaching consequences (Talebi Bezmin Abadi et al., 2019).

**Animal welfare: decrease an unprecedented number of animals in industrial livestock systems**

- **Animal slaughtering** – Reducing European meat production provides the opportunity to decrease the slaughtering of 584 million sentient animals in livestock systems on a yearly basis, even excluding for arguably hundreds of millions of aquatic animals (FAO, 2023).
- **Animal welfare standards** – Reducing animal-sourced food from intensive livestock and increasing plant-based or foods with high animal welfare standards can improve welfare for animals raised, transported and slaughtered, for example for the European herd of ~20 million living dairy cows (Eurostat, 2024).

**Socio-economic: enhancing value of food and its producers**

- **Food production & the position of farmers** – Protein diversification could impact European agricultural production, which is currently of vital socio-economic importance with its employment of 4.1% of Europe's total workforce, including in rural areas with limited other sources of income, and generation of 1.3% of the EU's total gross value added (Eurostat, 2024). Despite being supported by a significant share of subsidies , the position of European farmers within the agrifood system is documented to be under a multitude of pressures, which is highlighted by a reduction of a quarter of total farms over the last decade, a lack of generational renewal, deterioration of farmers' bargaining position driven by downstream consolidation and concerns about unfair trading practices (Eurostat, 2024;

EC, 2024; AGRI-Committee, 2024). The livelihood of farmers and their agricultural production is at risk by an interplay of climate change, pollution and biodiversity loss (Blattner et al., 2025). Although protein diversification provides an opportunity to avoid or build resilience to these negative environmental impacts, there are uncertainties about its socio-economic effects (Rieger et al., 2023).

- **Food demand & dietary patterns** – The agrifood system generates vital nutrients for human consumption, serving a myriad of European diets with a cultural and social value far exceeding the sum of its ingredients. Although inequitably distributed, an average European diet consists roughly of 82 grams of protein per capita per day, split into 60% for animal-sourced and 40% for plant-based proteins. Both the total protein intake as the animal-sourced share is significantly higher than European dietary recommendations and the global average (Simon et al., 2024; Rieger et al., 2023). Dietary diversification is inherently complex and challenged by cultural and societal paradigms about food (Lumpsden et al., 2024). Recent academic research and pledges by European retailers focus on the enabling role of food environments to support dietary diversification by improving availability, affordability and desirability of plant-based and alternative-protein.
- **Global food security & competitiveness –** Protein diversification provides the opportunity to improve global food security by decreasing pressure from multiple impact areas, such as depletion of planetary resources, and reducing European livestock's dependency on imports of high-protein crops (JRC, 2024). Agricultural strategic autonomy has received increased attention driven by concerns about geo-political food security risks, with the weaponization of food production in the Russian war against Ukraine in particular (EU Council, 2025). However, food security is part of different narratives within protein diversification debates, ranging from enhancing net trade positions to ensuring that all people have access to healthy and nutritious food (Duluins et al., 2023). The extent to which these two food security interpretations can symbiotically enhance European sustainable competitiveness needs further research (Zibell et al., 2023).
- **Hidden economic costs** – Recent studies suggest that European food market prices lack significant 'hidden costs' and are thus not incentivizing food with the lowest environmental, health, animal welfare and socio-economic opportunity costs (Funke *et al*. 2022, FAO). The FAO recently estimated the 'hidden costs' of the European agrifood system at a 2.4 trillion in US dollars at purchasing power parity over 2020, predominantly driven by environmental and health externalities (FAO, 2024). These estimations from the FAO could be a starting point for further research on hidden costs within the European agrifood system to improve incentives towards a sustainable agrifood system.

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