Legumes Translated Practice Guide 2

The role of legume production and use in European agri-food systems

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Legumes Translated

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This practice guide provides a synthesis of the work done in the Legumes Translated project for contract deliverables 4.1, 4.2 and 5.2. The reports which build the basis are Deliverable 4.1 Viable cropping systems for competitive value chains, Deliverable 4.2 Integration of legume production at farm level, Deliverable 5.2 Multi-criteria guidance on developing legume cropping. For further information on data sets and assessments of cropping systems and feed rations see Deliverable Report 4.2 and 5.2. The reports are here available: https://cordis.europa.eu/project/id/817634/results/de.

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The role of legume production and use in European agri-food systems

Summary

Legumes can play a crucial role in making European agri-food systems more sustainable by improving the environmental performance as well as resource-efficiency and contributing to a higher level of protein self-sufficiency. Based on considerations of current legume production and consumption in Europe, this guide illustrates effects of integrating legume in cropping and consumption systems and discusses thereby agronomic, environmental and economic effects. It is shown that European legume cropping and use still do not play a significant role, although there seems to be a very slow reversal of the decline in legume consumption and production in agri-food systems. Legume crops showed clear impacts on environment-friendly production systems and protein self-sufficiency. However, the economic performance and particularly the competitiveness of legumes build a considerable challenge for the (re-)integration in European farming which makes specific efforts for developing market outlets and value chains in order to rise legume selling prices and for raising crop performance using genetic and agronomic improvement necessary. Policy interventions that support an increase of legumes' on-farm performance and competitiveness as well as foster sustainable protein consumption patterns are therefore key.

Keywords: Legumes, cropping systems, environment, economics, agronomy, pre-crop effects, feed ration

Introduction

Legumes can play a crucial role in making European agri-food systems more sustainable by improving the environmental performance as well as resource-efficiency and contributing to a higher level of protein self-sufficiency. Discussions on the need for shifting diets have identified legumes as an important alternative to animal protein that enables considerable environmental and health impacts. Despite these often promoted advantages, legume production and consumption does not play a significant role in recent agri-food systems which is shown by current production and consumption patterns in the European Union (EU).

We have built the guide on findings from three prior reports in which we compiled knowledge from previous projects and literature and analysed our project partners' data on cropping systems and feed rations. In order to compare effects from legume-supported cropping systems to reference cropping systems without legumes, we gathered data from our project partners in 17 study areas in nine European countries. In total we collected 24 grain legume and seven forage legume-supported cropping systems and 22 reference systems and assessed them with agronomic, economic and environmental indicators. Feed rations were provided from partners active in the pig and aquaculture sector.

Production areas of legumes, cereals and oilseed crops in the European Union

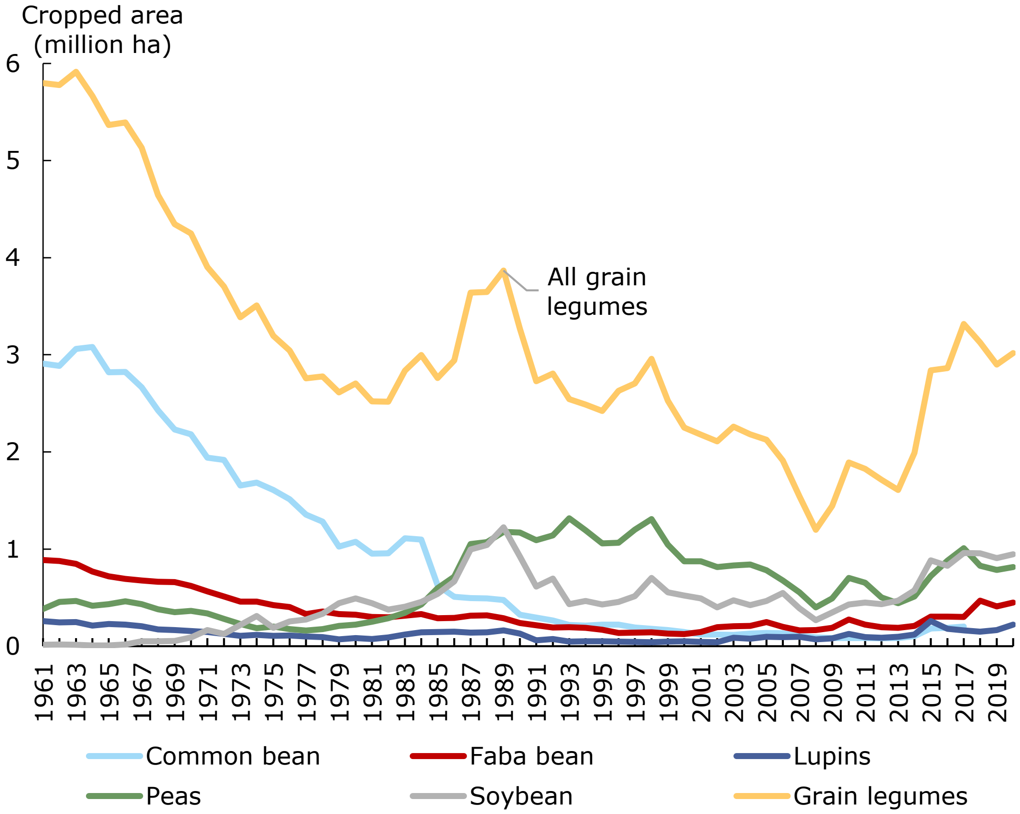

Figure 1. Changes in production areas of grain legumes in the EU-27 from 1961 to 2020 (in million ha). (Source: FAOstat - Production sheet)

The total production area of grain legumes in the EU has declined from almost 6 million ha in 1961 to 3 million ha in 2020 (Figure 1), being equivalent to a decline from almost 5% of arable land used for grain legumes in 1961 to about 3% in 2019.[1] An increase in the production area since the 2010s has majorly been caused by changes in the Common Agricultural Policy that support legume production with several instruments. While in 1961 common bean was the most widely cultivated grain legume, used exclusively for human consumption, today soybeans and peas are the predominant grain legumes whose main use is animal feed, followed by field beans and even smaller acreages of lupins.

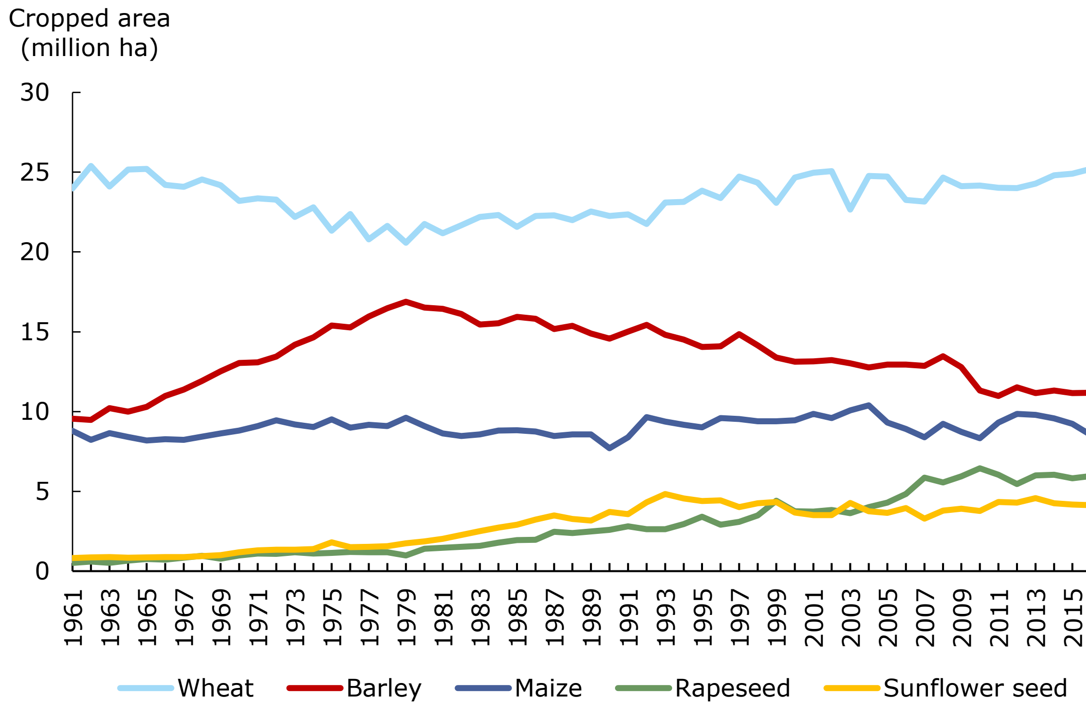

Figure 2. Production areas of different cereal and oilseed crops in the EU-27 from 1961 to 2020 (in million ha) (Source: FAOstat)

Comparison of the production areas of major cereal and oilseed crops shows the emphasis of European production systems on these crops. Wheat as the mostly cultivated crop, dominates cereal cropping in Europe and production areas have remained at about 22-25 million ha when considering snapshots of 1961 and 2020 (Figure 2). Barley and maize production areas make each about 10 million ha in 2020 which are also comparable to the areas in 1961, despite in-between changes in areas devoted to barley production. The share of total cereal production area is more than 50% of the EU arable land.[2] Oilseed crop production has increased since 1961 to about 4 million ha for sunflower and 5 million ha for rapeseed production in Europe, adding up to over 10% of the total arable land dedicated to sunflower and rapeseed. These cropping

[1] Summarized grain legumes include chick pea, common bean, cow pea, faba bean, lentil, lupin, pea, soybean, vetches and in FAOstat not specifically specified grain legumes because of their minor relevance at the international level.

[2] Including barley, maize, oat, rye, triticale, wheat and mixed grain (a mixture of cereal species that are sown and harvested together).

shares illustrate the current specialization on few, major crops in Europe, involving mostly cereals and oilseed crops.

European protein consumption

In the area of human consumption, legumes play in most parts of Europe a minor role (Figure 3), even though signals of increasing consumer interest in legumes caused by the rise in plant-based and flexitarian diets and a growing number of innovative legume products have recently been reported.[3] [4] Consumers in Southern Europe traditionally eat most legumes, but have shown highest decreases in per capita consumption with about 5 kg in 2019 compared to over 7 kg in 1961. In Eastern Europe consumption dropped also to 2 kg in 2019. Western Europe showed in the past lowest consumption rates, but increased the consumption to also 2 kg in 2019. Northern Europe expanded its legume consumption compared to 1961, but also to a rather low average consumption of 3.4 kg.

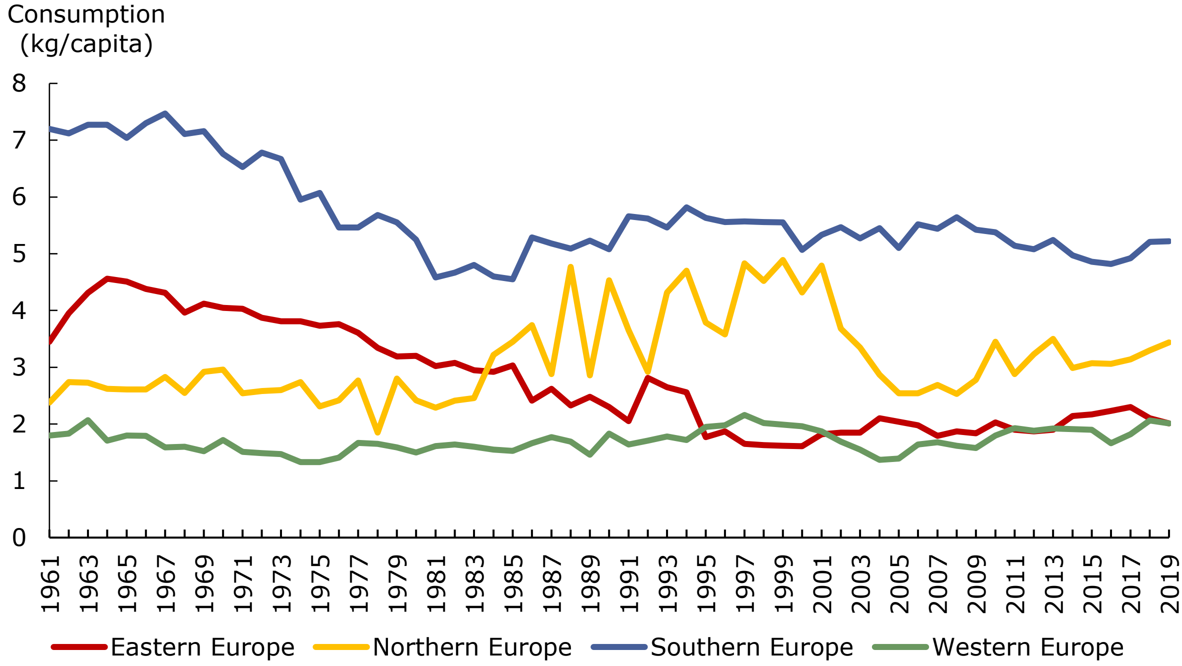

Figure 3. Annual average per capita consumption of grain legumes in European regions from 1961 to 2019 (Source: FAOstat)

The very low legume protein intakes are highly contrasting with animal protein intakes. Considering exemplary the development of consumption patterns of meat shows increases in all European regions - to over 70 kg in 2019 (Figure 4).[5] Since it was shown

[3] Including bambara beans, chick peas, common beans, cow peas, faba beans, lentils, lupins, peas, pigeon peas, pulses flour, pulses bran, soybean, vetches and in FAOstat not specifically specified grain legumes because of their minor relevance at the international level. Data sheets used: until 2010 'Food Balances (-2013, old methodology and population)' and for 2010-2019 'Food Balances (2010-)'.

[4] European Commission 2018. Directorate-General for Agriculture and Rural Development, Market developments and policy evaluation aspects of the plant protein sector in the EU: final report https://data.europa.eu/doi/10.2762/022741

[5] Including bovine meat, mutton & goat meat, pigmeat, poultry meat and item 'other meat' (e.g. horse meat, camel meat, rabbit meat, game meat). Data sheets used: until 2010 'Food Balances (-2013, old methodology and population)' and for 2010-2019 'Food Balances (2010-)'.

that for every 1 kg of meat protein about 6 kg of plant protein is required, these consumption patterns also depict a dramatically high need in plant protein supply.[6]

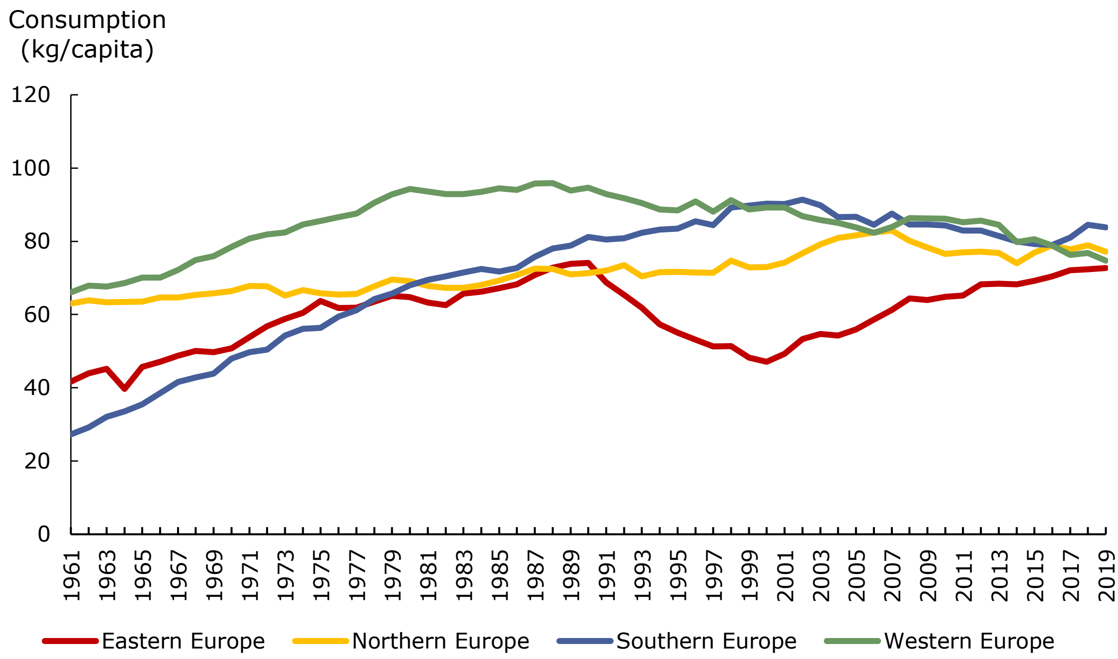

Figure 4. Annual average per capita consumption of meat in European regions (in kg/capita/year) from 1961 to 2019 (Source: FAOstat)

The EU is for the most part self-sufficient in livestock products, therefore the increased meat consumption came along with a sharp increase in livestock production since 1961 (Figure 5). The summarized production of beef, pig and poultry meat reached in 2020 almost 45 million t which equals nearly three times the production in 1961. Increases in production were mostly made in pig and poultry meat. The very high cereal production in Europe enables to cover the cereal-based components of the feed rations. But in order to cover the enormous amount of high protein crops needed for these livestock production systems, soybean imports were raised steadily to almost 35 million t. Total grain legume production in the EU increased despite the decreases in area under legumes due to productivity gains, but the gains cannot cover the needs from the livestock sector at all.[7]

[6] Pimentel, D., Pimentel M. 2003. Sustainability of meat-based and plant-based diets and the environment. American Journal of Clinical Nutrition 78, 660-663.
[7] Grain legume production including chick pea, common bean, cow pea, faba bean, lentil, lupin, pea, soybean, vetches and in FAOstat not specifically specified grain legumes because of their minor relevance at the international level.

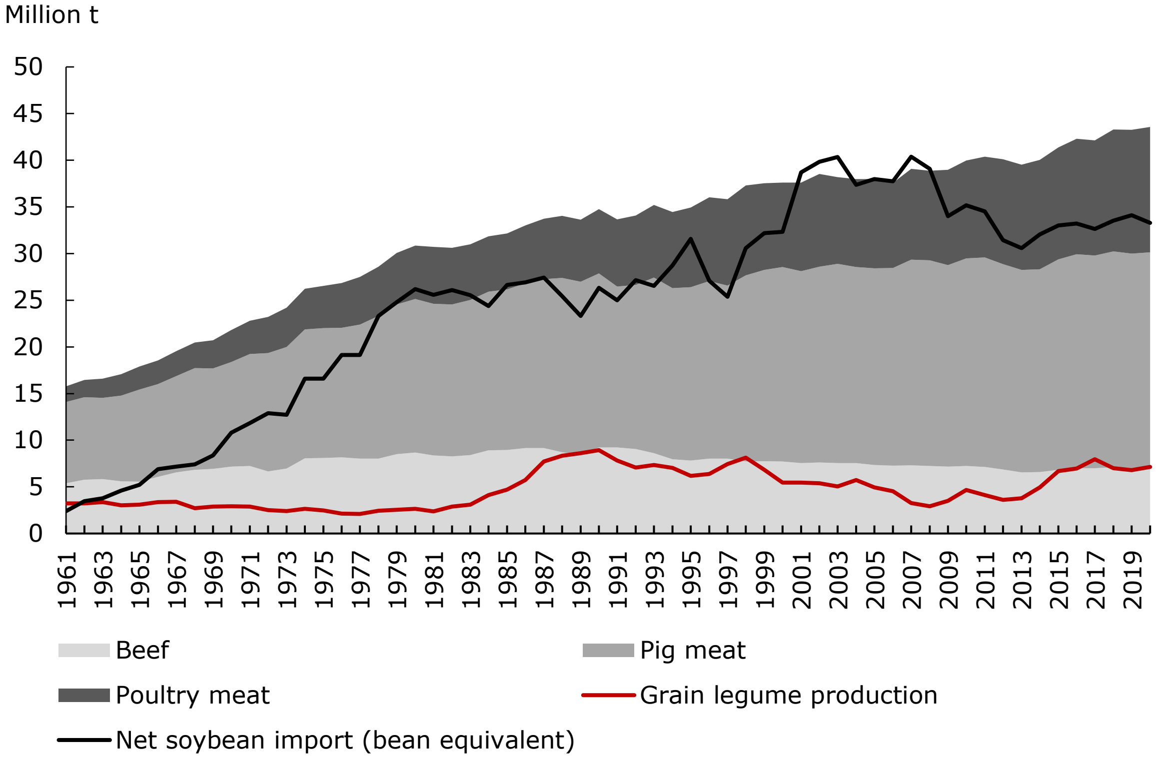

Figure 5. Production of meat, grain legumes and net soybean import in the EU-27 from 1961 to 2020 (Source: FAOstat)

Based on these introductory considerations of legume production and consumption in Europe, this guide provides insights into challenges and effects of legume cropping and use and highlights agronomic, environmental and economic implications of an increased legume integration in European agriculture.

Yield and yield stability

In order to understand the low cropping shares of legumes in Europe, the topic of yield and yield stability of legume and non-legume crops is crucial.

Cereals grow particularly well in Europe

Generally, grain legumes have lower yield levels compared to cereal crops in Europe due to their higher protein content and higher oil content in the case of soybean and lupin. While the yield potential of cereals has considerably increased starting with the Green Revolution until the beginning of this century, yield increases of legumes were relatively small.[8] Yield trends from 1961 to 2019 of wheat and pea as a main grain legume in Germany, one example of the major producers in the European Union, display these varying developments (Figure 6).

[8] Watson, C., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C., Vanhatalo, A., Zander, Z., Murphy-Bokern, D., Stoddard, F. 2017. Grain legume production and use in European agricultural systems. Adv. Agron. 144, 235–303.

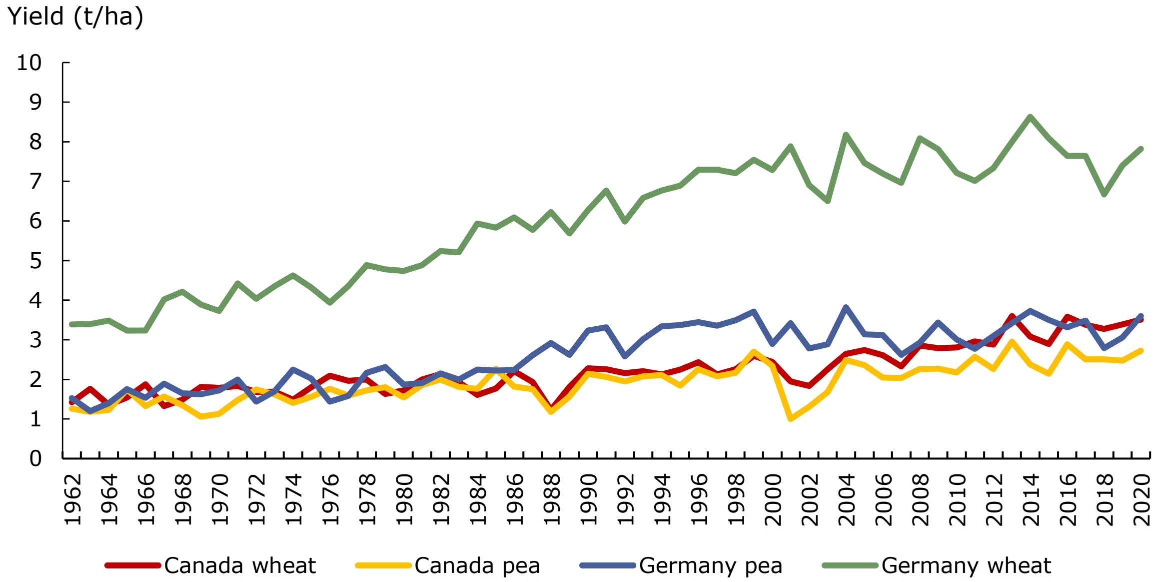

Figure 6. Changes in annual average yields of wheat and pea in Germany and Canada (Source: FAOstat)

Cereals' noticeable yield increases were enabled through focused breeding activities that led to genetic improvement, the switch to autumn sowing which exploits the comparative advantage that Europe's milder climate provides, and the increased use of nitrogen fertilisers and pesticides. Compared to these advancements, the investments and consequently also the achieved technological progress in legume production were minor which contributed to the present situation where wheat yields are double than those of major grain legumes. This considerable yield advantage of cereals over grain legumes is a specific characteristic of the arable sector in Europe, which is shown when comparing yield trends of wheat and pea in Canada (Figure 6). The development of wheat and pea yields in Canada were closely aligned and also pea yield in Germany had a comparable development. However wheat yields in Germany increased significantly. Therefore, wheat yields in Europe have shown particular increases which resulted in a situation in which the EU has the highest wheat yields in the world which was caused by the advancements described above, but also as a consequence of the European climate and natural conditions. This yield advantage is a major reason for European farmers to produce cereals and not legumes.

The yield of grain legumes is more stable than commonly claimed

Besides lower yield levels, also yield stability of legumes is considered to be problematic and named in farmer surveys as one of the main arguments against growing grain legumes.[9] Yield fluctuations can occur for example due to legumes' poor competitiveness against weeds, susceptibility to lodging, drought stress, pests, diseases or legumes' indeterminate growth habit.[10] Options to decrease yield variability through agronomic

[9] Zimmer, S., Liebe, U., Didier, J.-P., Heß, J. 2016. Luxembourgish farmers' lack of information about grain legume cultivation. Agron. Sustain. Dev. 36, 2.

[10] Bues A., Preissel, S., Reckling, M., Zander, P., Kuhlmann, T., Topp, K., Watson, C., Lindström, K., Stoddard, F.L., Murphy-Bokern, D. 2013. The environmental role of protein crops in the new common agricultural policy, in: Agriculture and rural development. European Parliament, Brussels; http://edepot.wur.nl/262633.

management are limited, indicating the need for genetic improvement.[11] However this strong negative perception on yield stability of legumes was challenged with recent evaluations. It was shown that yield fluctuations of legumes are likely to be overestimated in analysis which can be caused for instance by inadequate datasets for comparisons. While legumes are often cultivated on less productive soils and smaller areas, other crops for comparisons are grown on all types of soils and larger areas, resulting in a scale-dependent bias. Analysis based on crops grown under same soil and management conditions have shown that yield stability of legumes is similar to those of other spring-sown crops. However, compared to winter cereals, spring-sown grain legumes are significantly less stable.[12]

Considering the results from our practice-based partners' cropping systems, the comparisons from legume-supported arable cropping systems to their reference system without legumes (considering all crops in the rotation) showed in over 80% of cases no differences in yield stability greater than -2%p (percentage points) to +2%p found (Figure 7). Only in individual cases, legume systems showed higher or lower yield stability compared to their reference systems. However, these differences were on a low level (+3%p to -6%p), considering the rotational outputs.

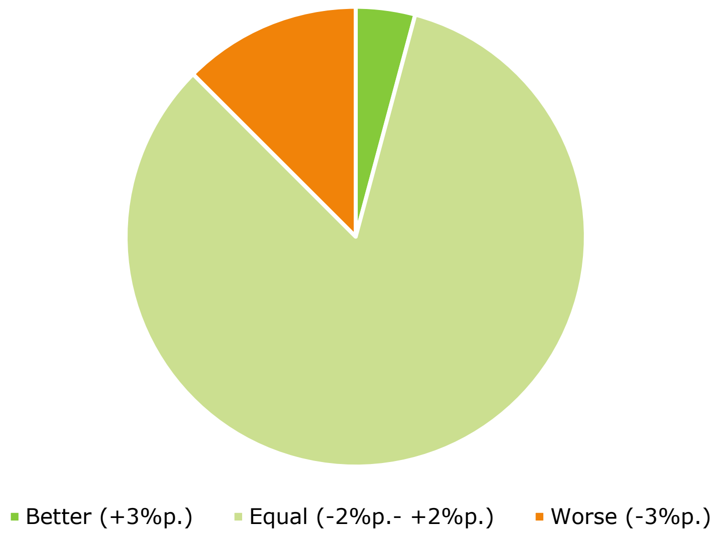

Figure 7. Differences in yield stability in percentage points (%p) of legume-supported arable cropping systems compared to reference cropping systems (considering all crops in the rotation)

Environmental and resource impacts

Legumes positively impact the environment and resource-efficiency in agri-food systems. This statement was proven in numerous studies and evidence was provided with results from field experiments, modelling approaches or reviews. In order to retrace these effects it is necessary to consider firstly agro-ecological processes and qualities inherent to legumes and secondly their effects on environment and resource use.

[11] Zander, P. Amjath-Babu, T.S., Preissel, S., Reckling, M., Bues, A., Schläfke, N., Kuhlman, T., Bachinger, J., Uthes, S., Murphy-Bokern, D., Stoddard, F., Watson, C.A. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36,1–20.
[12] Reckling, M., Döring, T.F., Bergkvist, G., Stoddard, F.L., Watson, C.A., Seddig, S., Chmielewski, F.-M., Bachinger, J.,2018. Grain legume yields are as stable as other spring crops in long-term experiments across northern Europe. Agron. Sustain. Dev. 38, 63.

Nitrogen related effects
Pre-crop effects of legumes comprise a nitrogen and break-crop effect.[13] The nitrogen effect refers to the higher provision of nitrogen to the following crop. The biological nitrogen fixation enables legumes to be nitrogen self-sufficient, consequently requiring no nitrogen fertilisation. The nitrogen carry over-effect depends a higher amount of nitrogen carried over to the next crop compared to the carry over from other crops, usually cereals. Hence, there is a considerable potential for reducing nitrogen fertiliser inputs in cropping systems including legumes. How much nitrogen is fixed depends on several factors such as temperature, water availability and legume species.[14] For instance, forage legumes are able to fix more nitrogen because of their high biomass production and longer growth period.[15] The results of the assessment of our data showed that grain legume-supported cropping systems considerably reduced the nitrogen fertiliser inputs (by more than 20%) compared to the reference systems in 80% of comparisons (Figure 8). In the forage cropping systems, legume integration resulted in all cropping systems in a considerable reduction of nitrogen fertilisers (Figure 9). The absence of nitrogen fertiliser in the year of the legume crop was the main contributor to the total fertiliser savings over the rotations complemented by site-dependent nitrogen input reductions in the following crops.

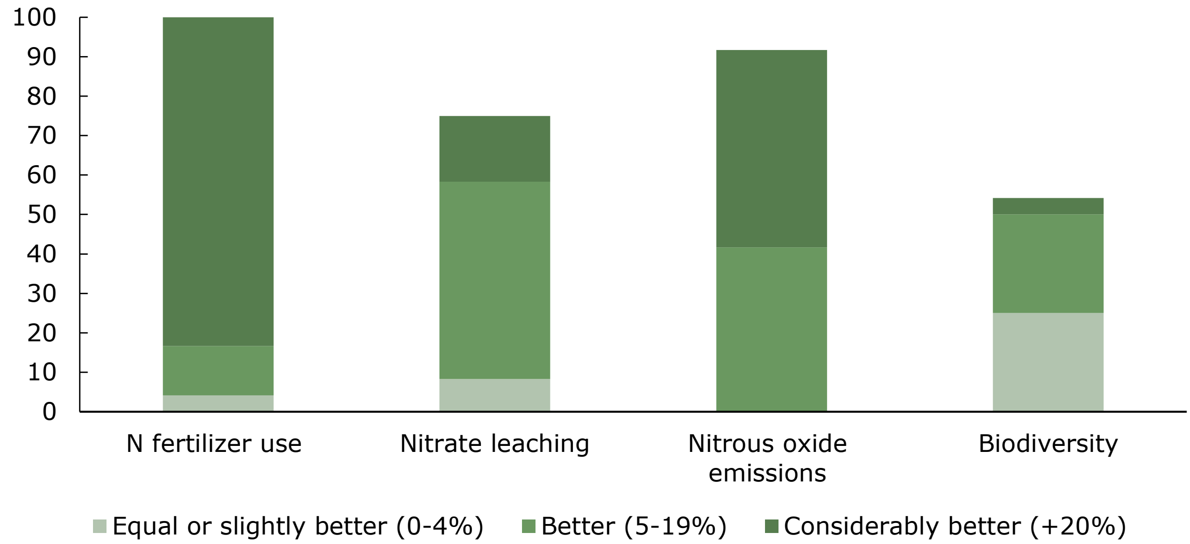

Figure 8. Share (%) of legume-supported arable cropping systems performing better than their reference cropping system in environmental assessment

Besides the on-farm resource effects due to reduced nitrogen fertiliser needs, large-scale resource effects can also be generated. An overall reduced nitrogen fertiliser demand would cause a reduced fossil energy use in the production of synthetic fertilisers which would induce an environmental impact with decreased greenhouse gas emissions (GHG)

[13] Chalk, P.M. 1998. Dynamics of biologically fixed N in legume-cereal rotations: a review. Aust. J. Agric. Res. 49, p. 303–316.
[14] Watson, C., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T. Topp, C., Vanhatalo, A., Zander, Z., Murphy-Bokern, D., Stoddard, F. 2017. Grain legume production and use in European agricultural systems. Adv. Agron. 144, 235–303.
[15] Carlsson, G., Huss-Danell, K. 2003. Nitrogen fixation in perennial forage legumes in the field. Plant and Soil, 253(2), 353-372.

from fertiliser manufactories.[16] Reduced industrial emissions are not the only environmental impact caused by the nitrogen effect. Legume cropping can lower nitrous oxide emissions from agricultural soils since there is a strong correlation between the emissions and the application of nitrogen fertilisers. During the growing phase legumes emit little nitrous oxide while in the period after the harvest emissions could be higher, indicating the need for adequate management options for residues and the use of cover crops.[17] In our analysis, we found that in over 90% of the arable cropping systems and in 100% of the forage cropping systems with legumes, the nitrous oxide emissions were lower than in their reference systems (Figure 8; Figure 9).

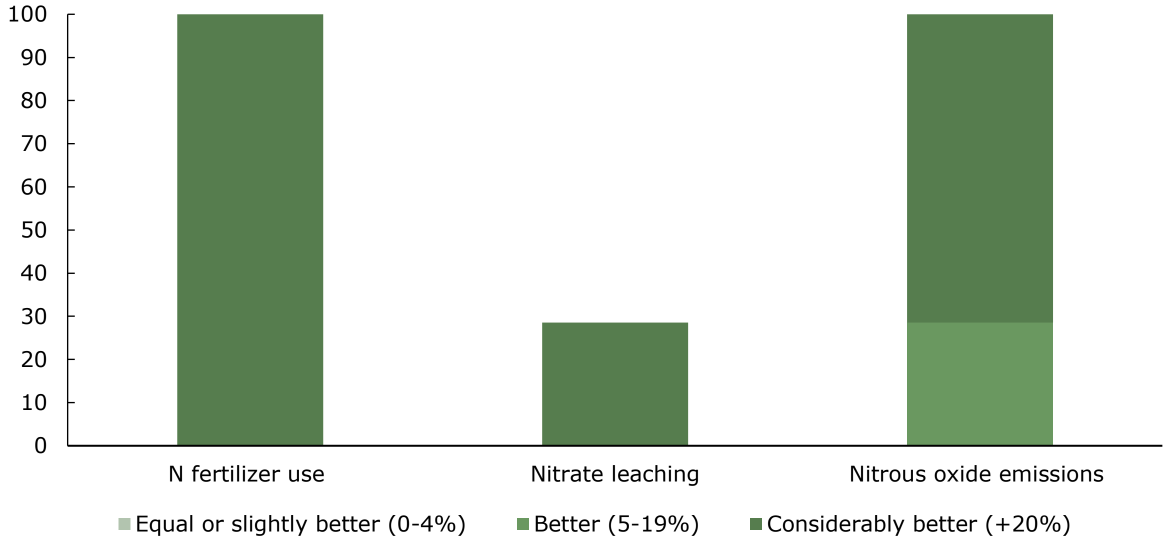

Figure 9. Share (%) of legume-supported forage cropping systems performing better than their reference cropping system in environmental assessment

Lastly, N-related effects can be shown in the context of nitrate leaching. Nitrate dissolved in soil water can pollute water resources and thereby harm vulnerable ecosystems.[18] Leaching is affected by a range of aspects including the quantity of available nitrate in the soil, soil texture and structure and the volume of drainage water.[19] Legumes can impact leaching positively as well as negatively. By decreasing the overall nitrogen fertiliser use, legumes can reduce the risk of leaching. However, the nitrogen-rich residues of legumes can also contribute to an increased leaching.[20] In order to reduce this risk, management strategies such as early sowing of winter crops after legumes,

[16] Zander, P. Amjath-Babu, T.S., Preissel, S., Reckling, M., Bues, A., Schläfke, N., Kuhlman, T., Bachinger, J., Uthes, S., Murphy-Bokern, D., Stoddard, F., Watson, C.A. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36,1–20.
[17] Watson, C., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T. Topp, C., Vanhatalo, A., Zander, Z., Murphy-Bokern, D., Stoddard, F. 2017. Grain legume production and use in European agricultural systems. Adv. Agron. 144, 235–303.
[18] Zander, P. Amjath-Babu, T.S., Preissel, S., Reckling, M., Bues, A., Schläfke, N., Kuhlman, T., Bachinger, J., Uthes, S., Murphy-Bokern, D., Stoddard, F., Watson, C.A. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36,1–20.
[19] Plaza-Bonilla, D., Nolot, J.M., Raffaillac, D., Justes, E. Cover crops mitigate nitrate leaching in cropping systems including grain legumes: Field evidence and model simulations. Agriculture, Ecosystems and Environment 212, 1–12.
[20] Bues A., Preissel, S., Reckling, M., Zander, P., Kuhlmann, T., Topp, K., Watson, C., Lindström, K., Stoddard, F.L., Murphy-Bokern, D. 2013. The environmental role of protein crops in the new common agricultural policy, in: Agriculture and rural development. European Parliament, Brussels; http://edepot.wur.nl/262633.

intercropping or the cultivation of catch and cover crops can be applied.[21] Our assessment of practice-based cropping systems showed that more than 65% of the legume-supported arable cropping systems reduced the nitrate leaching compared to their reference systems (Figure 8). Besides, almost 10% of the grain legume systems performed equally or slightly better than their reference systems. From the legume-supported forage cropping systems about 30% showed reduced nitrate leaching compared to the reference system (Figure 9). Higher leaching results in the remaining 70% of the forage legume systems were, however, caused by other crop rotation changes (additional introduction of winter wheat which was not present in the reference system) than the legume introduction.

Effects on pests, soil properties and biodiversity

The break crop effect is not legume-specific but can also be achieved by other break crops such as sunflower or rapeseed that have positive effects on monotonous crop sequences through diversification. By breaking cycles of soil-borne diseases and reducing pressure from weeds and pests, the potential of diseases, weeds and pests is reduced.[22] Consequently, pesticide applications can potentially be reduced in crops after break crops, inducing on-farm resource effects as well as environmental impacts through reduced pesticide emissions to water bodies.[23] However, the use of pesticides in the year of legumes should not be underestimated since the majority of broad-leaved break crops receive similar amounts of pesticides as most cereals.[24]

There are also effects of legumes on soil properties. Due to legumes' root growth, low C/N ratios of legume residues (that are more similar to that of soil properties than of other non-legume crops) and legume-specific changes in soil microorganisms several positive effects are achieved. Soil structure is enhanced with an increased water-absorbing capacity and a reduction in soil compaction.[25] These on-farm resource effects are further complemented by the possibility to reduce cultivation energy in legume-supported cropping systems.[26] Both nitrogen and break crop effect also enable increased yields of subsequent crops.

[21] Watson, C., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C., Vanhatalo, A., Zander, Z., Murphy-Bokern, D., Stoddard, F. 2017. Grain legume production and use in European agricultural systems. Adv. Agron. 144, 235–303.

[22] Böhm, H., Dauber, J., Dehler, M., Gallardo, D., de Witte, T., Fuß, R., Höppner, F., Langhof, M., Rinke, N., Rodemann, B., Ruehl, G., Schittenhelm, S. 2020. Crop rotations with and without legumes: a review. Journal für Kulturpflanzen 72, 489-509.

[23] Bues A., Preissel, S., Reckling, M., Zander, P., Kuhlmann, T., Topp, K., Watson, C., Lindström, K., Stoddard, F.L., Murphy-Bokern, D. 2013. The environmental role of protein crops in the new common agricultural policy, in: Agriculture and rural development. European Parliament, Brussels; http://edepot.wur.nl/262633.

[24] Kirkegaard, J.A., Christen, O., Krupinsky, J., Layzell, D., 2008. Break crop benefits in temperate wheat production. Field Crops Res. 107, p. 185–195, http://dx.doi.org/10.1016/j.fcr.2008.02.010.

[25] Watson, C., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C., Vanhatalo, A., Zander, Z., Murphy-Bokern, D., Stoddard, F. 2017. Grain legume production and use in European agricultural systems. Adv. Agron. 144, 235–303.

[26] Preissel, S., Reckling, M., Schläfke, N., Zander, P. 2015. Magnitude and farm-economic value of grain legume pre-crop benefits in Europe: a review. Field Crops Res. 175, 64–79.



Faba bean © Seedtech Soybean growth © IFCNS Narrow-leaved lupin © ZALF

The described legume features of biological nitrogen fixation and low C/N ratios have, jointly with further attributes of legumes such as their specific flowering habits, the potential to positively impact above and below ground biodiversity.[27] Existing knowledge on the impacts on biodiversity through legume integration in crop rotations is so far very limited, but previous studies indicate that legumes can affect wild arable flora, insects and vertebrates. The biodiversity assessment of our arable cropping systems showed in most cases no considerable differences between legume-supported and reference system. In 25% legume systems performed equally or slightly better (Figure 8). Differences of worse performing legume systems to their reference systems were mostly negligible with decreases of -1% to -3%. Almost 30% of the legume systems performed better than their reference systems, which was mainly caused by the replacement of maize by either grain legumes or winter wheat, since maize showed particularly low species diversity scores.

Mitigating feed and food related environmental impacts through legumes

Another process that characterises legumes is the protein synthesis which enables all legume species to provide high-quality protein for food and feed.[28] In this context European-grown legumes are often seen as a valuable opportunity to replace the in the feed sector majorly used imported soybean and thereby also impact its resource and environmental effects. The impacts of substituting imported soybean and soybean products with European-grown legumes depend on a multitude of factors in terms of crop production (production methods, yield levels or cultivars) and also livestock production (feeding values of different components make changes in feed rations necessary, changes in animal productivity and excretions) which makes the assessment highly complex. Life-cycles analysis that compared animal products fed with European-grown legumes and imported soybean came therefore to diverse results, however, indicating environmental effects of European-grown legumes in terms of energy use, GHG emissions and acidification.[29]

Considering the food sector, there are clear environmental impacts from the use of legumes in human diets. Replacing animal-based protein sources with plant-based

[27] Böhm, H. Dauber, J., Dehler, M., Gallardo, D., de Witte, T., Fuß, R., Höppner, F., Langhof, M., Rinke, N., Rodemann, B., Ruehl, G., Schittenhelm, S. 2020. Crop rotations with and without legumes: a review. Journal für Kulturpflanzen 72, 489-509.

[28] Murphy-Bokern, D. Peeters, A. Westhoek, H. 2017. The Role of Legumes in Bringing Protein to the Table. In: Murphy-Bokern, D., Stoddard, F., Watson, C. (Eds.), Legumes in cropping systems. CABI, Oxon.

[29] Bues A., Preissel, S., Reckling, M., Zander, P., Kuhlmann, T., Topp, K., Watson, C., Lindström, K., Stoddard, F.L., Murphy-Bokern, D. 2013. The environmental role of protein crops in the new common agricultural policy, in: Agriculture and rural development. European Parliament, Brussels; http://edepot.wur.nl/262633.

protein from legumes would largely improve environmental impacts of diets since it would decrease GHG emissions as well as pressure on land and water resources.[30]

Profitability

The trend towards simplified cropping systems dominated by cereals is mainly attributed to the short-term economic performance of different crops. Farmers focus on crops that ensure high revenues and mostly do not consider legumes as profitable crops. The key factors impacting profitability of marketed legumes are yield and prices. While farmers' perception on legumes' yield level and yield stability has already been described as adverse, price levels and drivers for legumes' market prices are in the following shortly presented and conclusions on legumes' competitiveness are drawn.

Farm prices for crops

Farm prices paid to grain legume producers are low.[31] An exception is the market price of soybean, which is approximately twice that of other grain legumes (Figure 10).[32]

Prices of legumes are influenced by various factors such as the market segment in which a legume is sold. The by far largest amounts of legumes are sold on the feed market, higher prices, however, can be achieved on the food market.[33] The feed market is also further distinguished in a conventional and a premium segment, the latter referring to a non-genetically modified feed segment where there are considerable price premia. Another impacting factor is the farming system. Prices of organic legumes are estimated double than those from conventional systems.[34]

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[30] Ferreira H., Pinto E., Vasconcelos M.W. 2021. Legumes as a Cornerstone of the Transition Toward More Sustainable Agri-Food Systems and Diets in Europe. Front. Sustain. Food Syst. 5:694121.

[31] Preissel, S., Reckling, M., Bachinger, J., Zander, P. 2017. Introducing legumes into European cropping systems: farm-level economic effects, in: Murphy-Bokern, D., Stoddard, F.L., Watson, C.A. (Eds.), Legumes in Cropping Systems. CABI Publishing, 209–225.

[32] Böhm, H. Dauber, J., Dehler, M., Gallardo, D., de Witte, T., Fuß, R., Höppner, F., Langhof, M., Rinke, N., Rodemann, B., Ruehl, G., Schittenhelm, S. 2020. Crop rotations with and without legumes: a review. Journal für Kulturpflanzen 72, 489-509.

[33] European Commission 2018. Directorate-General for Agriculture and Rural Development, Market developments and policy evaluation aspects of the plant protein sector in the EU: final report https://data.europa.eu/doi/10.2762/022741

[34] Sepngang, B. K., Stauss, W., Stute, I., Mergenthaler, M. 2018. The market of grain legumes in Germany. First results of the EU-project LegValue.

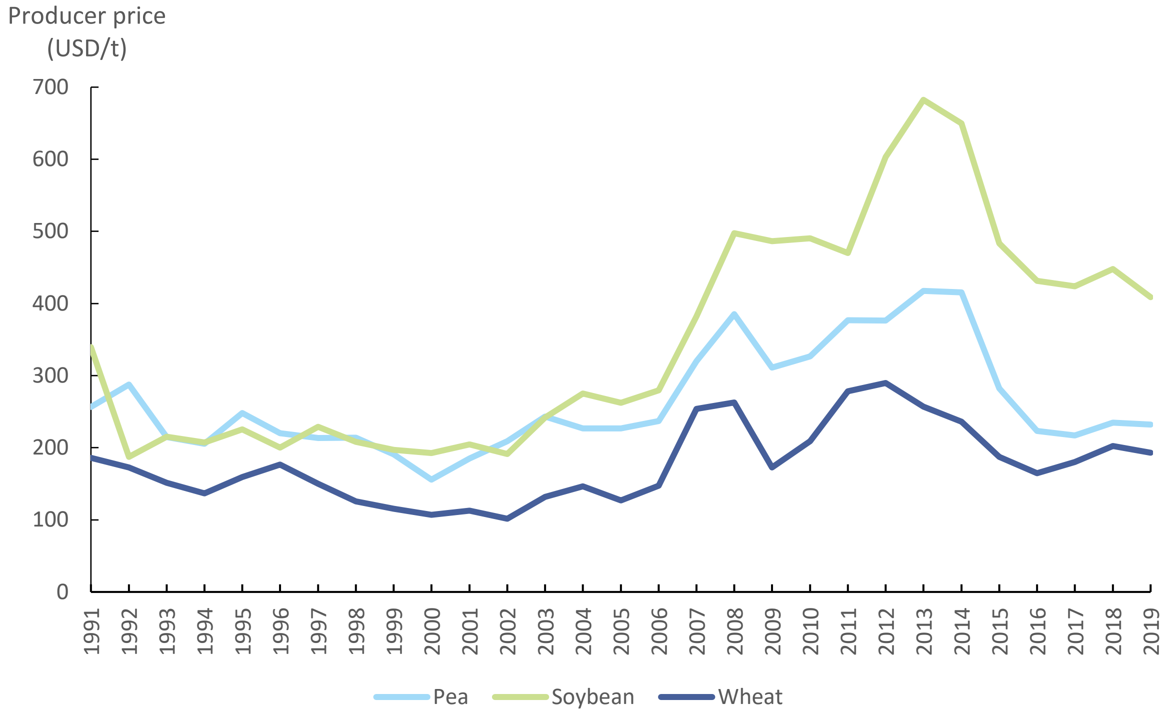

Figure 10. Changes in producer prices for pea, soybean and wheat in major EU producer countries: Bulgaria, France, Poland, Spain and the UK (Source: FAOstat – Prices sheet)

Drivers for price changes in the different sectors have been described with a continuously increasing global demand for soybean owing to a steadily increasing livestock production and the growing demand from China, a consumer-driven demand for more non-GM and organic products, and an expansion of the food segment with more innovative legume-based products.[35]

Particularly, price developments of soybean were drastic in the last two decades: Producer prices have more than doubled since 2000 in the EU (Figure 10) and the latest developments show once again a severe price increase on the world market (Figure 11) which is closely correlated with the EU soybean prices. High soybean prices can also impact other grain legume prices as those are becoming more interesting options for substituting expensive soybean products (especially in the feed market), however, these are often traded on national or regional markets where missing marketing structures and the focus on direct interaction can lead to price formations that are not linearly connected to global trends.

[35] European Commission 2018. Directorate-General for Agriculture and Rural Development, Market developments and policy evaluation aspects of the plant protein sector in the EU: final report https://data.europa.eu/doi/10.2762/022741

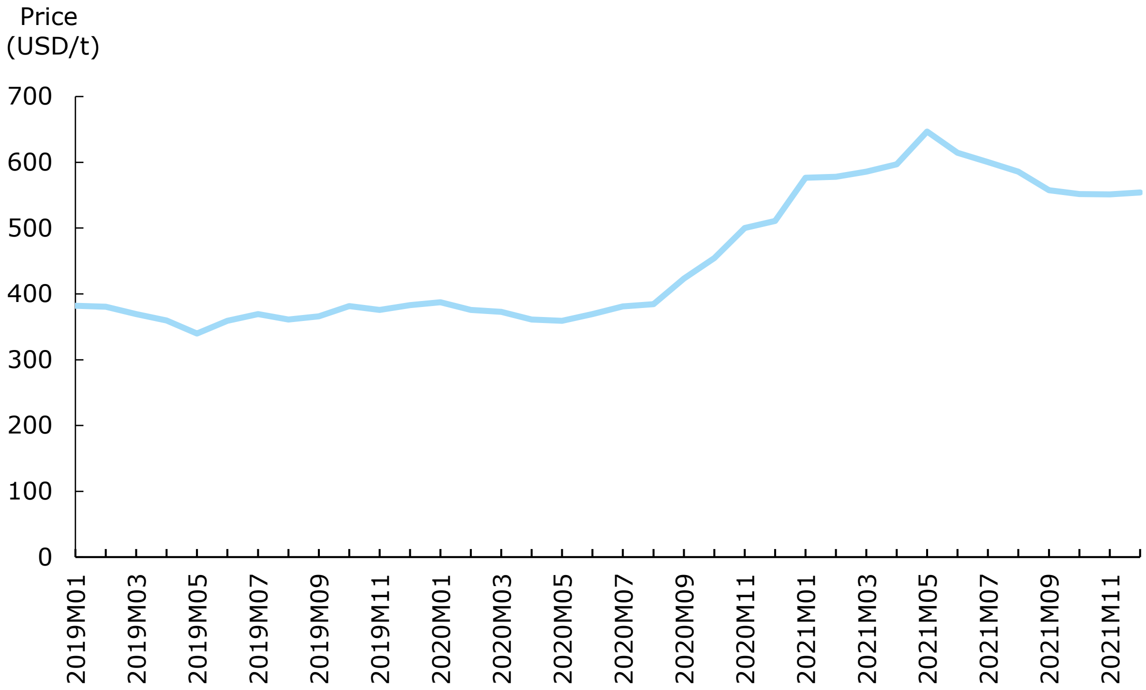

Figure 11. Changes in monthly global soybean prices January 2019 to December 2021 (Source: World bank)

Considering conventional gross margin analysis, the described yield and price levels of legumes result – especially for legumes other than soybean – in the vast majority of cases in gross margin deficits compared to non-legume crops which can go up to several hundred euros per hectare.[36] These deficits are particularly severe when comparisons are made with most profitable crops such as wheat. However, suitable comparisons that refer to crops with similar agronomic roles in the crop rotation and average profitability can lead to lower deficits or even comparable economic performances. The lacking competitiveness of legumes make farmers use their land for the cultivation of non-legume crops such as cereals, maize, rapeseed or sunflower.[37] The comparative advantage of cereals in Europe is thereby most prominent.

Improving the on-farm economic performance of legumes

Conventional gross margin calculations, however, miss to include resource effects of legumes. Single elements of the pre-crop effects can be transferred into economic terms including cost reductions and increased revenues of following crops. The cost reductions are thereby determined through fertiliser and pesticide savings as well as reductions in tillage. Increased revenues are caused by increased yields in subsequent crops. The extent of the yield effects are dependent on the reduction of nitrogen fertiliser. If nitrogen fertilisation is significantly reduced in the subsequent crop, the yield increase is smaller, but if nitrogen fertilisation is kept at the same level as without legumes, the

[36] Preissel, S., Reckling, M., Schläfke, N., Zander, P. 2015. Magnitude and farm-economic value of grain legume pre-crop benefits in Europe: a review. Field Crops Res. 175, 64–79.
[37] Ditzler, L, van Apeldoorn, D.F., Pellegrini, F. Antichi, D., Bàrberi, P., Rossing, W.A.H. 2021. Current research on the ecosystem service potential of legume inclusive cropping systems in Europe. A review. Agronomy for Sustainable Development 41: 26.

yield increase can be raised to highest levels.[38] In practice, many farmers do not adapt the fertilisation after legumes, since they see the additional nitrogen merely as a bonus, but do thereby miss to make full usage of the pre-crop value of legumes.[39] Quantifications of cost reductions and increased revenues are partly difficult to make and estimations vary also depending on the crop chosen for comparison.

Rotational gross margin analysis enable the resource effects to be taken into account and create thereby a more realistic picture of legumes' effect on farm economic performance. Former analyses have shown that legumes' competitiveness increases considerably when assessments are based on rotational level.[40] [41] The evaluation of our own data set showed that almost 40% of all arable cropping systems with legumes had a similar or better gross margin than their reference cropping systems (Figure 12).[42] When considering only cropping systems with soybean the share was raised about 20% and it was also only including cropping systems that had at least 5% or even more than 20% higher gross margins than their reference systems. For forage cropping systems, we found that more than 70% of the systems with legumes achieved considerably higher gross margins. This was largely caused by cost reductions in fertilisation and yield effects in following crops.

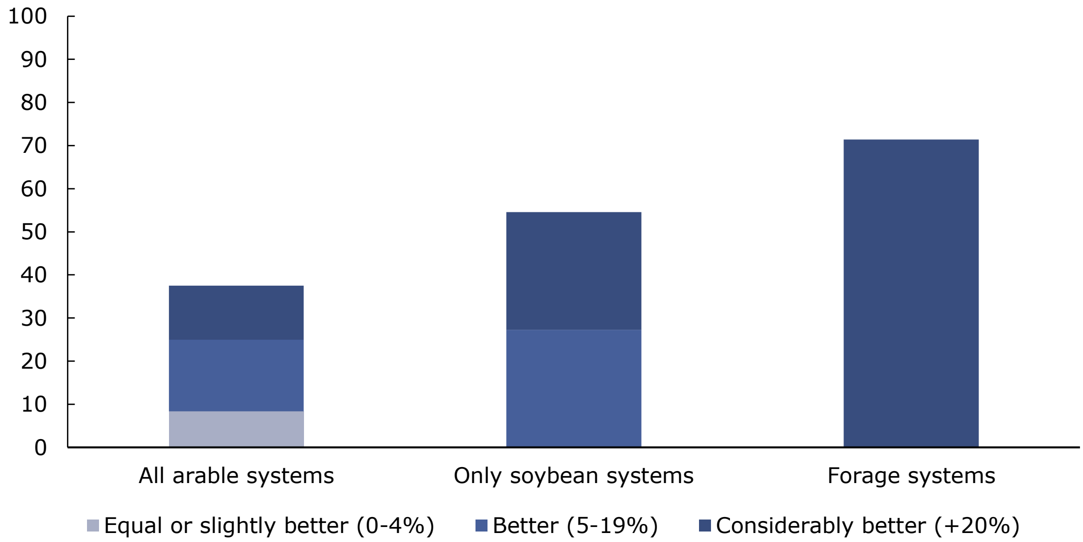

Figure 12. Share (%) of legume-supported cropping systems performing better than their reference cropping system in gross margin analysis

Besides the consideration of rotational profitability, legumes' economic performance can also improve in light of changing competitive conditions. With increasing costs of crop inputs, the value of the resource savings through legume integration grows. Depending

[38] Preissel, S., Reckling, M., Bachinger, J., Zander, P. 2017. Introducing legumes into European cropping systems: farm-level economic effects, in: Murphy-Bokern, D., Stoddard, F.L., Watson, C.A. (Eds.), Legumes in Cropping Systems. CABI Publishing, 209–225.
[39] Bues A., Preissel, S., Reckling, M., Zander, P., Kuhlmann, T., Topp, K., Watson, C., Lindström, K., Stoddard, F.L., Murphy-Bokern, D. 2013. The environmental role of protein crops in the new common agricultural policy, in: Agriculture and rural development. European Parliament, Brussels; http://edepot.wur.nl/262633.
[40] Preissel, S., Reckling, M., Schläfke, N., Zander, P. 2015. Magnitude and farm-economic value of grain legume pre-crop benefits in Europe: a review. Field Crops Res. 175, 64–79.
[41] Jouan, J., Ridier, A., Carof, M., 2019. Economic drivers of legume production: approached via opportunity costs and transaction Costs. Sustainability 11, 705.
[42] Gross margin calculations included revenue based on crop yield and price as well as direct variable costs of production, but did not include labour costs and subsidies.

on fertiliser prices and producer prices for either livestock or crop products there can be a tipping point reached that makes the inclusion of legumes profitable. The ratios of nitrogen fertiliser prices and producer prices have changed since 2000 and the growing fertiliser-to-product ratios show an increasing attractiveness of legumes (Figure 13). Since mineral fertiliser production is highly energy intensive, the increasing energy prices are likely to continue this development.[43]

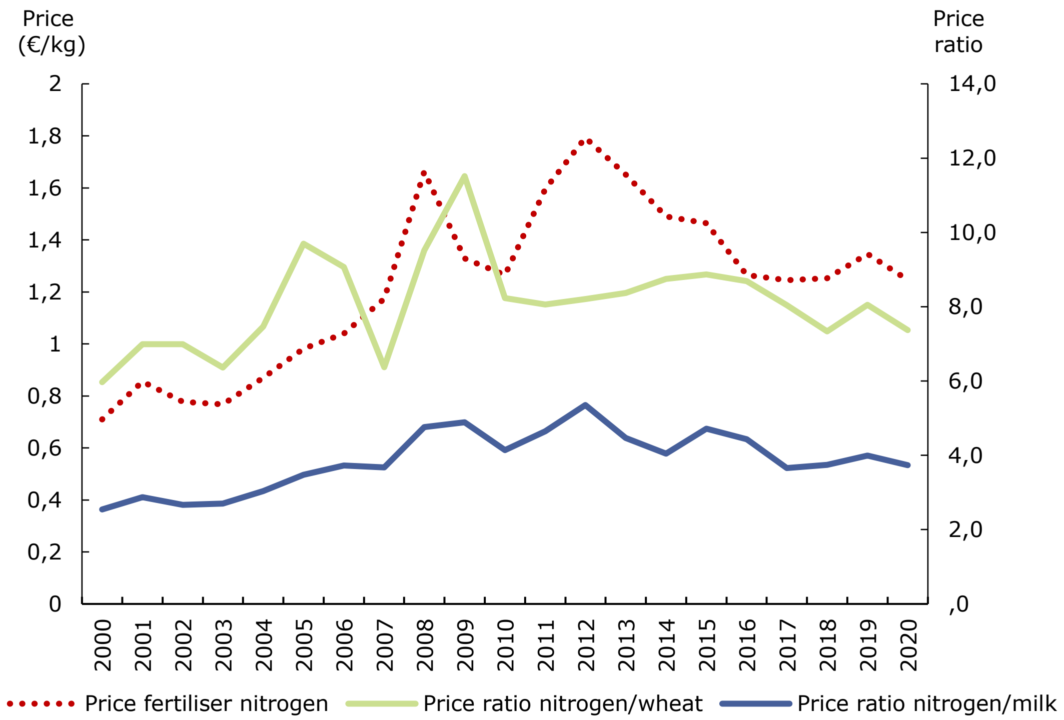

Figure 13. Changes in urea fertiliser price and associated fertiliser/ product price ratio in the EU-27 (Source: Eurostat - Agricultural prices and price indices)

As described earlier, increasing prices for imported soybean can also positively impact European legumes' economic performance. Considering price forecasts for both, nitrogen fertilisers and soybean (Figure 14), the on-farm competitiveness of non-legume crops, particularly nitrogen-intensive crops such as cereals and maize, is likely to decrease further in the future.

[43] Hasler, K., Bröring, S., Omta, S.W.F., Olfs, H.-W. 2015. Life cycle assessment (LCA) of different fertilizer product types. European Journal of Agronomy. 69, 41-51.

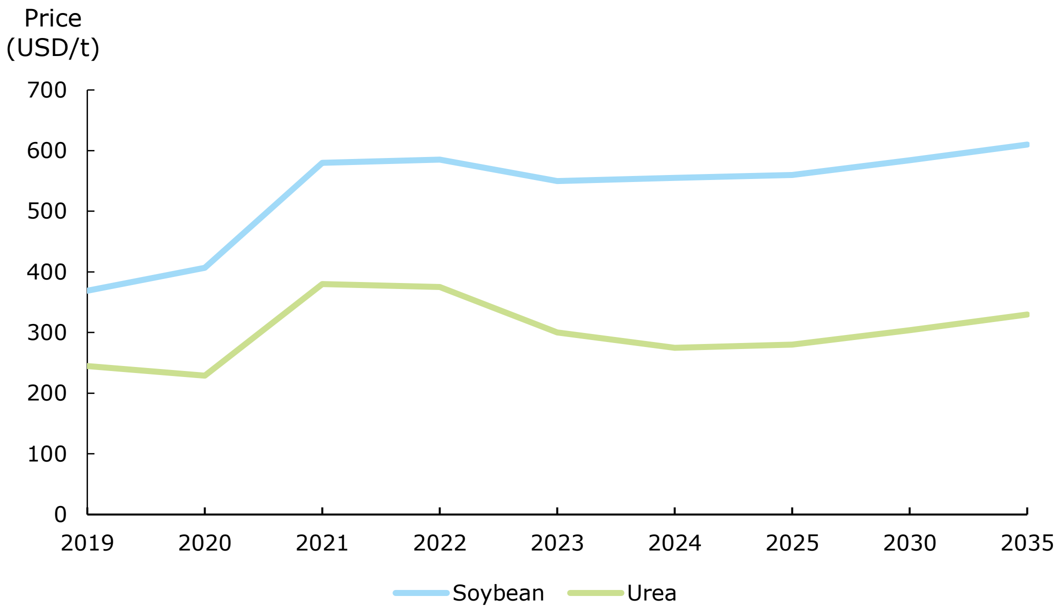

Figure 14. Global soybean and urea price forecast (Source: World bank)

Integrating policies to support crop diversification using legumes

Even though there are market developments that support improved economic performance of European legumes and the real farm-level economic value is higher than conventional gross margin calculations indicate, legumes still lack economic attractiveness for most farmers. Therefore, policy interventions for promoting European legumes have been demanded in numerous policy recommendations.

Within the last reform of the Common-Agricultural Policy in 2013, several legume-supporting instruments were introduced. Member states can provide nationally specific voluntary coupled support for legumes, legumes are included in the greening measures and also within the rural development programmes for instance through agri-environment-climate measures. These agricultural subsidies function thereby as financial incentives for producing legumes and hence directly impact legumes' economic performance. However, public support for legumes can also come from other policy areas and indirectly influence legumes' profitability. Environmental policies for climate protection such as a carbon tax, biodiversity conservation or nutrient management could affect legumes based on their positive environmental and resource impacts, while market policies could impact through trade regulations or information-based instruments.

In the analysis of our own data set on cropping systems, we have considered the effects of voluntary coupled support, agri-environment-climate measures and a potential carbon tax of 50 €/t CO_{2eq} levied on synthetic nitrogen fertilisers.

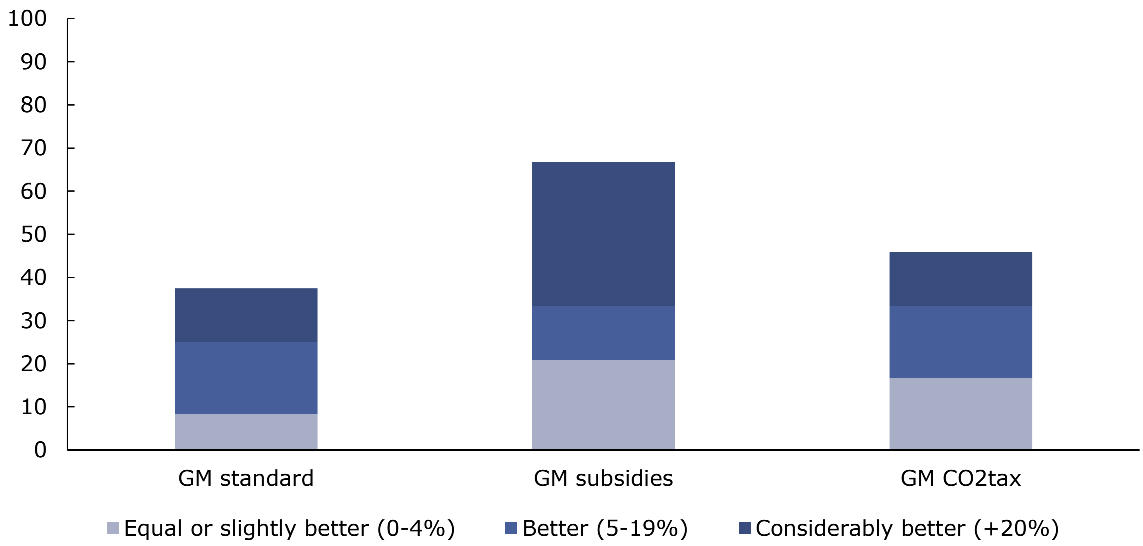

Figure 15. Share (%) of legume-supported arable cropping systems performing better than their reference cropping system in economic assessment

The impact of the measures from the Common-Agricultural Policy was substantial when comparing it with the results from the standard gross margin (Figure 15). While only about 40% of the arable legume-supported cropping systems had equal or higher gross margins than their reference system, this share was raised to almost 70% when subsidies were included. Effects modelled through the carbon tax were smaller and could only increase the share of equal or slightly better performing legume systems.

The assessment showed the considerable impact of single policies on the economic performance of legume-supported cropping systems and also stresses the importance for supporting legumes in the new period of the Common-Agricultural Policy with eco-schemes and further measures. However, it is obvious that not a single policy - especially when focusing only on supporting the production of legumes - is able to induce a lasting change to more European legumes. An integrated policy approach is needed that covers several fields, including value chain organisation, consumer information and action in research and knowledge transfer.[44]

Legumes for food and feed

Ecosystem services of legumes have been shown with their supporting and regulating services, but legumes do also contribute to provisioning services. By providing food and feed legumes play an important role in human and livestock diets. As a source of micro- and macronutrients legumes deliver protein, energy in the form of starch or oil, soluble and insoluble fiber, vitamins and bioactive phytochemicals.[45]

[44] European Commission 2018. Directorate-General for Agriculture and Rural Development, Market developments and policy evaluation aspects of the plant protein sector in the EU: final report https://data.europa.eu/doi/10.2762/022741

[45] Watson, C., Stoddard, F. 2017. Introduction – Perspectives on Legume Production and Use in Agriculture, in: Murphy-Bokern, D., Stoddard, F.L., Watson, C.A. (Eds.), Legumes in Cropping Systems. CABI Publishing, 1–17.

The contribution of legumes to protein supplies

Particularly, in their role as protein-rich crops, legumes have become a crucial factor in the protein supply for Europe. While forage legumes' protein content is slightly lower, all grain legume species provide high-quality protein in their seed, ranging from 20% in common bean up to 40% in soybean. Cereal crops' protein contents are not only considerably lower, the amino acid profile also differs, making a complementation through legumes necessary.[46] When considering EU citizens' daily protein consumption from 2018, the share of animal protein is by far the largest with 59%, followed by cereal protein with 28%, 3.5% from vegetables and only 1.7% from legumes.[47] A dietary change to an increased plant-protein intake with legumes and a decreased animal product consumption would not only cause considerable environmental benefits, but would also improve health.[48] Hence, a growing number of food guidelines classify legumes as a protein source and recommend them as an animal protein alternative.[49]

Due to the focus on animal-protein intake and the considerably increased livestock production, the feed sector is the main consumer of plant-based protein in the EU.[50] Through providing 57% of the high-yielding cereal production to the livestock sector, the EU reached self-sufficiency in this supply, however for protein-rich crops there is a huge deficit of 71% which is majorly covered through imports of soybean and soybean products.[51]

Our analysis of cropping systems with and without legumes, showed the potential of legume-supported arable systems to tackle this deficit. In more than 70% of all legume-supported arable systems there was a by at least 5% or even by over 20% increased protein output compared to their reference systems (Figure 16). These impacts in protein output induced a trade-off in terms of energy output. Because of legumes' comparable gross energy content to cereals and their lower yield levels, the energy output of 90% of the legume-supported cropping systems were found to be smaller compared to their reference systems. Considering, however, the European production deficit of protein-rich crops and dependency on imports, contrasted with the specialization in high-yielding cereal production and net export of cereals, this trade-off seems tolerable and can be rather understood as a chance to promote Europe's protein self-sufficiency.

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[46] Watson, C., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C., Vanhatalo, A., Zander, Z., Murphy-Bokern, D., Stoddard, F. 2017. Grain legume production and use in European agricultural systems. Adv. Agron. 144, 235–303.

[47] FAOstat 2021. Food balances; https://www.fao.org/faostat/en/#data/FBS

[48] Costa, M.P., Reckling, M., Chadwick, D., Rees, R.M., Saget, S., Williams, M. and Styles, D. 2021. Legume-Modified Rotations Deliver Nutrition With Lower Environmental Impact. Front. Sustain. Food Syst. 5:656005.

[49] Magrini M-B, Anton M, Chardigny J-M, Duc G, Duru M, Jeuffroy M-H, Meynard J-M, Micard V and Walrand S 2018. Pulses for Sustainability: Breaking Agriculture and Food Sectors Out of Lock-In. Front. Sustain. Food Syst. 2:64.

[50] European Commission 2018. Directorate-General for Agriculture and Rural Development, Market developments and policy evaluation aspects of the plant protein sector in the EU: final report https://data.europa.eu/doi/10.2762/022741

[51] Murphy-Bokern, D. Peeters, A. Westhoek, H. 2017. The role of legumes in bringing protein to the table. In: Murphy-Bokern, D., Stoddard, F., Watson, C. (Eds.), Legumes in cropping systems. CABI, Oxon.

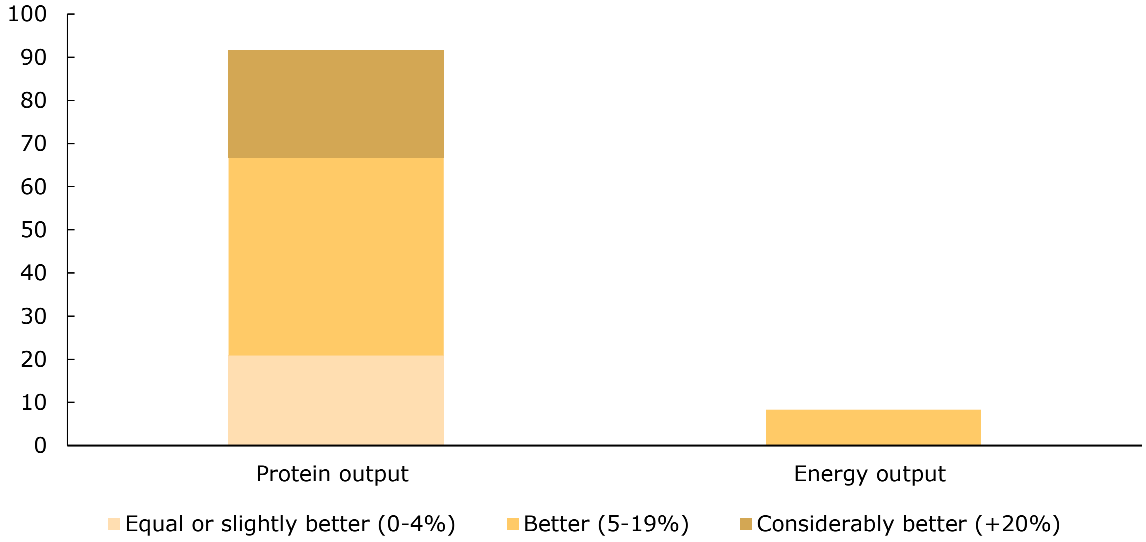

Figure 16. Share (%) of legume-supported arable cropping systems performing better than their reference cropping system in agronomic assessment

Legumes' competitive feed use – the relative value of feed ingredients

However, in order to actually substitute imported soybean with European legumes, they do not only have to be integrated in cropping systems, they also have to pass as a competitive feed in livestock production systems. Determining factors in the feeding sector are input prices of feed components and their nutritional value - only if these are satisfied, an uptake of new feed components is likely. The consideration of the relative price of a specific feed is thereby key. It reflects the monetary value that a feed has compared to other alternative feeds based on its specific nutrient or energy content.[52] This "value for money" is based on the content of ingredients that determine the feed value. In simple calculations often only protein and energy content are considered, however more sophisticated assessments take additional value factors such as feed value-limiting components (e.g. antinutritional factors) also into account. Feed-specific restrictions (e.g. maximum amounts, additional treatments such as toasting) for the individual animal species or categories must always be taken into account when looking for an exchange of a feed that is worth the price. A common approach are optimization methods that allow the calculation of relative prices. For assessing the relative prices with optimization models, so-called comparison or standard feeds are determined, and the evaluation of the exchangeability is calibrated to their quality and their price development on the feed market. This allows to compare actual feed value of potential feed components with their current market prices.

We have applied this approach on our Europe-wide data from the cropping system analysis and found in all cases considerably higher feed values than reported market prices (Figure 17). The extent of the undervaluation varied depending on the reported legume market prices and the national prices for wheat and soybean that were taken as comparison feeds in the calculation.[53]

[52] Steinhöfel, O. (ed.), 2008. Untersuchung und Bewertung von Futtermitteln für Wiederkäuer: eine gemeinsame Empfehlung des Landesarbeitskreises. „Futter und Fütterung im Freistaat Sachsen". Sächsische Landesanstalt für Landwirtschaft, Dresden.
[53] Prices for alternative feed ingredients (toasted extracted soybean meal and fodder wheat) were retrieved from Eurostat, 2018; https://ec.europa.eu/eurostat/data/database.

The greatest effect was found for pea in Bulgaria for which the calculated feed value was almost double as high as the market price. A very high soybean meal price of 419 €/t and the very low market price of pea caused the extreme difference. Pea market prices in Germany were between 20%-25% lower with 193 €/t, 200 €/t and 203€/t compared to 256 €/t for the calculated feed value. The difference between feed value with 275 €/t and market price with 235 €/t was smallest in the case study from Scotland.

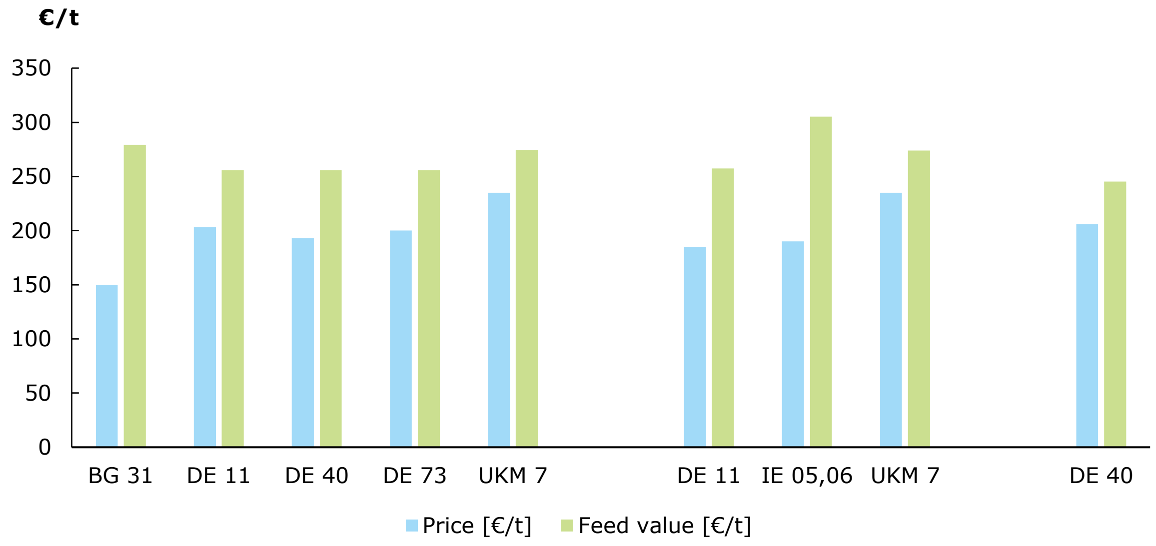

Figure 17. Reported market prices of pea, faba bean and lupin and calculated feed value based on purchase prices for alternative feed ingredients from actors in study areas situated in different NUTS 2 regions

The faba bean price reported from German project partners was lowest with 185 €/t. The Irish price with 190 €/t was slightly higher and in both cases the comparison with the calculated feed value showed a considerable undervaluation of faba bean on markets. The Irish example displayed a high price difference with a 38% higher feed value, adding 115 €/t to the reported price. High prices for the alternative feed ingredients with 409 €/t for soybean meal and 221 €/t for feed wheat were the reason for the high increase for faba bean in the feed value. In Scotland, the reported price for faba bean was also only 14% lower than the calculated feed value. The lupin price of 206 €/t given from the study area in Brandenburg was 39 €/t lower than its calculated equivalent economic value of 245 €/t, which showed the same issue for lupin in receiving adequate prices on markets.

Differences between reported market prices and calculated feed value of pea, faba bean and lupin were found in all considered study areas, in some cases more extreme with almost doubled feed values and in some cases less severe. Therefore, the results stress the undervaluation of faba bean, lupin and pea in a range of European regions, indicating the potential for increasing market prices as well as their higher attractiveness for on-farm usage in mixed crop-livestock farming systems.

Practice-based insights into using legumes in pig production and aquaculture
In order to make this abstract considerations of European legumes in feeding more practice-related, we have also considered detailed feed rations in two important sectors – pig production and aquaculture.

Pig production

In pig production the supply of protein is particularly challenging, since a wide set of essential amino acids is necessary and usually imported soybean and soybean products are used to meet this demand. Within Legumes Translated, the association "Bäuerliche Erzeugergemeinschaft Schwäbisch Hall e.V." – BESH –, a Farmer Producers' Association of independent livestock farmers is focussing on how regionally grown legumes can more widely be used in their farmers' feed rations. Based on the association's input we therefore analysed four feed rations using different European grain legumes in order to gain insights on the competitive use of different legume feed ingredients. The exemplary feed rations refer to the early mast period of pigs from 28 kg upwards and are presented in Table 1.

Table 1. Feed ration composition with European GMO-free soybean (FR1), a ration with a reduced share of soybean replaced by pea (FR2); a pea, soybean mix (FR3); and a soybean-free ration based on pea, faba bean and rapeseed expeller (FR4)

Feed		FR 1: only soy	FR 2: reduced soy share, with pea	FR 3: pea soy mix	FR 4: pea, faba bean, rapeseed expeller
	Price (€/t)	%	%	%	%
Barley	163	35	30	33.5	30
Wheat	183	43	40	9	34
Maize	160			20.5	
Rye	127			9	
Soy (GMO-free)	565	19	12	13.5	-
Peas	215	-	15	10	10
Faba beans	210	-	-		8
Rapeseed expeller	309				15
Feed concentrate	639	3	3	3	3
Rapeseed oil	660			1.5	
Total price (€/t)		262	241	242	215

Considering the costs per ration the price advantage of the ration without European soybeans is noticeable. The soybean free ration (FR4) is 47 Euro cheaper per tonne than the ration with only soybean as a legume ingredient (FR1). Reducing soybean use only partially with pea (FR2 and FR3) can still reduce feed costs by 21 € or 20 € per tonne, respectively.

The nutrient composition of the rations (Table 2) illustrates that some of the minimal requirements for nutrients are not met by the soybean reduced or soybean free feed rations. While the standard ration with soybean (FR1) fulfills all nutritional requirements, the other rations (FR2, FR3, FR4) are slightly under the recommended value for crude protein, however some farmers state that this is still within an acceptable range. Additionally, the soybean free ration (FR4) has a lower than recommended energy content and the high share of rapeseed expeller could lead to rejection or low intake of the feed. These drawbacks make the ration a more experimental ration that needs thorough observation of the pigs' feeding and growing behavior.

Table 2. Nutrient composition of feed rations compared to recommended values

nutrient	recommended	FR 1 soy	FR 2 reduced soy share, with pea	FR 3: pea soy mix	FR 4: pea, faba bean, rapeseed expeller
ME ** MJ/kg	13	13.2	13.1	13.4	12.4
Crude protein (XP) g/kg	170	174.3	167.8	160	168.9
Lysine (Lys) g/kg	10	11.2	11.0	10.9	10.5
Methionine g/kg	3	3.2	2.7	2.8	2.7
Met & Cyst g/kg	6	6.6	5.9	4	6.3
Tryptophan g/kg	2	2.2	2.0	1.8	1.93
Threonine g/kg	6.6	7.6	7.1	7.1	7.1
Crude fiber (XF) g/kg	30	33.4	36.6	34.7	51.9

The analysis of pig feed rations with different European legume ingredients has shown that adequate feed rations are also possible without or a lower share of soybean. Pure price effects are thereby beneficial, but also small deviations from nutrient recommendations can occur which could have – but not necessarily have to – impact pig's feeding and growing behaviour. Individual cost analyses of rations including farm specific conditions and thorough consideration of pigs' feed intake and meat quality are therefore key and allow cost-efficient pig feeding based on regional legumes.

Aquaculture

An analysis in the production sector of aquaculture was implemented by the group "LegumesforFish" within Legumes Translated. A feed trial with locally produced legumes in fish feed formulas allowed to test alternative protein sources for feeding sea bream.

One lupin variant and on faba bean variant as well as two pea variants were tested in the feeding trial during a 86 day period. Each treatment received a feed formula with a relatively high share (10%) of legumes in order to see the nutritional effects in the feeding trials, replacing a part of the most plant origin raw materials used like soybean meal, sunflower meal and wheat flour (Table **3**). A typical commercial formula was used as a control. In order to meet the nutritional requirements, each ration had to be formulated separately, with fish meal and fish oil staying constant. The resulting costs of the final feed mix showed that the lowest costs can be achieved with lupin, followed by faba bean. The feed mix with both pea were slightly more expensive since the lower protein content of peas had to be balanced with shares of soy protein concentrate.

Table 3. Feed ingredients in fish feed, resulting costs per kg feed and cost difference with control

Raw materials	€/t	Control (%)	Lupin (%)	Faba bean (%)	Pea eliza (%)	Pea dodoni (%)
Fishmeal	1450	20.0	20.0	20.0	20.0	20.0
Soy protein concentrate	850	12.0	8.7	11.2	14.1	14.1
Corn gluten	750	19.8	19.8	19.8	19.8	19.8

Soybean meal	550	12.0	10.0	8.4	7.0	7.0
Sunflower meal	500	11.0	8.1	8.1	8.0	8.0
Wheat flour	250	10.9	9.7	8.3	7.0	7.0
Fish oil	1650	6.0	6.0	6.0	6.0	6.0
Salmon oil	1000	6.9	6.3	6.8	6.7	6.7
Premix	3500	1.0	1.0	1.0	1.0	1.0
Phosphorus	480	0.4	0.4	0.4	0.4	0.4
Lupin	460		10.0			
Faba bean	370			10.0		
Pea eliza	490				10.0	
Pea dodoni	490					10.0
Total		100.0	100.0	100.0	100.0	100.0
Feed cost €/t		894	877	882	906	906
Feed cost difference to control €/t			-20	-10	+10	+10

The results of the feed experiment are shown in Table 4. The trial with the lupin formula was not started since preliminary taste experiments showed that the fish did not feed on this formula, very likely due to an unpleasant taste related to the lupins. The faba bean mix which had a slightly lower feed cost resulted in almost equal feed costs as the control mix. Both pea mixes had higher feed costs per kg fish produced due to higher recipe costs and lower standard growth rates.

Table 4. Results of feed experiment with sea bream after a 60 day period; SGR: specific growth rate (per day); FCR: food conversion rate

	g/day	SGR	FCR	feed cost €/t fish produced	Difference nutrient cost
Control	0.45	1.09	1.18	1060	
Faba bean	0.43	1.06	1.21	1070	1.4%
Pea eliza	0.37	0.97	1.42	1290	21.6%
Pea dodoni	0.42	1.05	1.26	1140	8.3%

The feed experiments showed further potential for including legumes at considerable shares in fish feed for aquaculture. Especially in the context of rising soybean prices, the advantage of alternative legumes is becoming more and more obvious.

Main findings

- European legume cropping and use still do not play a significant role, although there seems to be a very slow reversal of the negative trends in legume consumption and production in agri-food systems.
- Legumes' potential for addressing pressing problems in our current agri-food systems such as greenhouse gas emissions, nutrient losses, biodiversity loss or excessive use of water and land resources have been shown with their effects for environment-friendly production and protein consumption systems.
- The economic performance and particularly the competitiveness of legumes build a considerable challenge for the (re-)integration in European farming. The consideration of current developments shows that there are trends which will automatically contribute to the increase of legumes' farm level profitability such as rising prices of agricultural inputs or imported soybean.
- Specific efforts for developing market outlets and value chains in order to rise legume selling prices and for raising crop performance using genetic and agronomic improvement will boost competitiveness further.
- Effective policy interventions that support an increase of legumes' on-farm performance and competitiveness as well as foster sustainable protein consumption patterns are therefore key.

About this practice guide

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Cover photograph: Flowering field pea in variety trials, Gülzow, Germany © Moritz Reckling

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