Legumes Translated

Legumes Translated Deliverable Report

Deliverable 4.1

Legumes Translated Development Guide: Viable cropping systems for competitive value chains

Due date: 4/2020

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Work package: Economic performance (WP4)

Work package leader: Johannes Schuler, ZALF

Relevant task: Economic assessment of legume-based production systems (Task 4.1);

Relevant task leader: Johannes Schuler, ZALF

Nature of deliverable: Report

Dissemination level: Public (PU)

Legumes Translated (Translating knowledge for legume-based farming for feed and food systems) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 817634

Objectives of the tasks supporting the deliverable

The background to this work is the need to address the comparative advantage of cereals and oilseeds that locks legumes out of farming systems and thus value chains. The overall goal is to help commercial actors identify and gain economic advantage. The findings are to be reported as development guides (practice guides) and summarised in practice abstracts (practice guides). Specifcally WP4 aims to:

1. identify economic opportunities and constraints at farm level for the introduction of legumes;
2. identify economic opportunities and constraints at sector and value chain level;
3. support the synthesis of actor groups' knowledge with economic validation; and
4. support the synthesis of transition networks' knowledge with economic validation.

The work reported here is covered by two tasks: Task 4.1 and Task 4.2 (both led by ZALF and involving all actor group representatives.

Task 4.1 (Economic assesment of legume-based production systems) supports actor groups with information on if and how competitive legume production can be implemented using e.g., gross margin calculations, success stories and benchmarking targeted considering the constraints identified in Task 3.1 and transition opportunities identified in WP6. The information gathered will include a number of scenario calculations to show the scope of conditions that lead to competitive and cost-effective production for selected actor groups. The discrepancies between production potentials and actual practice will guide the search for barriers at farm, value chain and sector level, which is also relevant information for policy makers. The results will flow into a development guide (D4.1) and practice abstracts (practice notes) and general secondary communications.

As set out in Task 4.1 of the project description of action (DoA), this contract deliverable report documents work that leads to the production of a Legume Translated development guide (practice guide) that examined the practical experience of the actor groups' as well as research reports. The compilation of economic information allows the identification of competitive conditions and cost-effective practices. The information gathered includes a number of scenario calculations to show the scope of conditions that lead to competitive and cost-effective production for selected actor groups. The discrepancies between production potentials and actual practice guide the search for barriers at farm, value chain and sector level, which is also relevant information for policy makers.

Activities undertaken

Costs and revenues are impacted by a range of economic drivers and determine farmers' crop choices. Farm-level yield and economic assessment data from the project partners and literature were compiled. The data set included several levels of considerations. Yield and producer price data as well as cost structures of legumes and non-legume crops for comparison were gathered. Simple gross margins of legumes and non-legumes as well as gross margins taking into account the pre-crop value of legumes were included. The gross margins across legume-supported rotations and similar rotations excluding legumes were also compared.

Following from the composition of the gathered material the guide considered at first the crop-level profitability from legumes alone and then compared to other crops. Secondly, the pre-crop value of legumes was highlighted and estimations of its magnitude were illustrated. Thirdly, analysis at the rotation scale were considered and different concepts to approach the rotation-level profitability described. Subsequently, an economic evaluation of the feed value of legumes was done. Lastly, legumes' potential to contribute to societal benefits and mechanisms for an economic evaluation of these benefits were analyzed and demonstrated.

In all steps the determining factors were described and illustrated with the exemple case regions from Legumes Translated. Based on the experiences within the actor groups of Legumes Translated, exemple data from Ireland, Germany, Serbia, Bosnia and Herzegovina and Finland were contributed by project partners. The material compiled was in the form of primary and secondary data. Primary data was collected through a data request that was sent out to all actor groups in order to gather data on regionally relevant cropping systems with and without legumes. Due to delays in the data gathering process only selected case studies – namely from the actor groups "German Soybean Association" and "Brandenburg Farmers' Network" could be included in this practice guide, others will be dealt with in forthcoming practice guides. The responsible organisation for the actor group "German Soybean Association" is the Centre for Agricultural Technolgy Augustenberg (LTZ) from which Jürgen Recknagel provided the data. "Brandenburg Farmers' Network" is represented by the project partner Leibniz Centre for Agricultural Landscape Reseach (ZALF). Moritz Reckling, Johannes Schuler, Renate Wille and Inka Notz were involved in the data collection at ZALF. Secondary data was provided from the actor groups "Soybean cultivation group in south-eastern Europe", "German Pea and Bean Network", "Ground for Growth" and "The Irish Grain Legume Group". Marjana Vasiljevic from the Institute of Field and Vegetable Crop provided data on behalf of the actor group "Soybean cultivation group in south-eastern Europe". Thorsten Haase and Ulrich Quendt from the Landesbetrieb Landwirtschaft Hessen (LLH) and Petra Zerhusen-Blecher from the Fachhochschule Südwestfalen contributed material in terms of the "German Pea and Bean Network". The "Ground for Growth" actor group is represented by the University of Helsinki and Casimir Schaumann contributed Finnish data. Irish data were found by the authors themselves, proceeding from an indicative guide to crop margins offered through Tim O'Donovan from Arvum Seed Technology. The named partners provided material that enclosed reports on crop production in their country and economic analysis of legume production. These sources were then used to relate the considerations from literature to these valuable insights from the actor groups in different regions.

Results

The work was conducted as planned in the description of action (DoA) with no deviations from plans. The draft text of the practice guide entitled Viable cropping systems for competitive value chains' (termed development guide in the DoA) is annexed. This will be subject to internal peer review and designed into a published practice guide.

This report for a practice guide examines the practical experience of Legumes Translated actor groups' as well as research reports on the economic aspects of legumes production. The compilation of economic information allows the identification of competitive conditions and cost-effective practices. By looking at the economic value of legumes at the individual crop level, it is shown which factors determine the profitability and which current developments on feed and food market can strengthen the position of European-grown legumes. The comparative advantage is discussed and reflected with insights on legumes' competitiveness in various regions, showing legumes' competitive power to several break crops. Expanding the analysis to the level of crop rotations allows to integrate legumes' pre-crop effects and resulting resource benefits to farmers are described. The importance to go beyond conventional gross margin analysis is underlined with approaches to assess the economic performance of cropping systems that can prevent economic underestimation of legumes and reveal their real economic performance. Legume prices are also discussed within the context of their value for animal feeding which shows potential to improve their crop-level economic value and simple tools for calculating the feed value are provided. The positive externalities for society caused by legume cutlivation are also discussed and exemplary measures to value the environmental benefits are presented.

Conclusions

Although grain legume production is increasing in Europe, legumes still does not play a significant role. The feed market has a major role in comparison to the food market, but the latter has considerable potential in terms of profitability as legumes targeted for food markets can generally achieve higher prices than feed-targeted grain legumes. European-grown legumes could also exploit consumers' interest and awareness in regional origin as well as environmental performance of products through labelling schemes and thereby achieve higher prices.

In conventional arable systems, farmers' cropping decisions are very strongly influenced by the economic competitiveness of each crop within cropping systems. Legume crops are generally regarded as not competitive in comparison with the most profitable cropping options. The information from our actor groups showed no case were legumes are the most profitable crop of a region. However, the profitability of faba bean in Ireland and Germany and the returns of pea in Finland and Germany were shown to be competitive in comparsion with other break crops. Soybean was shown to be even competitive with winter wheat in some situations.

For the most part, farmers in Europe are price takers. The prices they take are determined through the interplay of demand and supply on global or national markets. However, for specific contracts or production that serves serves premium markets (organic, non-GM, regional markets) there is some room for price negotiations. This is also true for a certain market share of soybeans, which profit from high prices and a high demand for EU-produce.

Overall, production costs play a decisive role for a profitable production of legumes. Keeping costs low, while yields increase through advances in practical knowledge and progress in breeding, can improve the chances of legumes gaining a higher market share.

The positive effect of legumes in crop rotations is possibly the most important factor in evaluating their benefits. However, the proper estimation of these benefits are the most difficult task. Thorough experiments and empirical work based on the comparison of a wide range of crop rotations in practice would allow a better understanding of these effects.

From a societal viewpoint, there are effects from legume cultivation that can be captured as positive externalities contributing to societal benefits. These environmental benefits include biodiversity enhancement, reduced nitrate leaching, lower emissions of greenhouse gases as carbon dioxide and nitrous oxide emissions or a reduction of international land-use changes if imports from oversea soybeans are reduced. European consumers will demand for even higher levels of EU legumes based on claims for less imports, no GM produce and arguments around climate change which demand for less synthetic fertilizers and an overall improved sustainability. Policy instruments such as a tax on CO_2 could also improve the competitiveness of grain legumes in European agriculture.

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20 April 2020 (updated 20 August 2020)

Legume Translated practice guide

Viable cropping systems for competitive value chains

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April 2020 (updated August 2020)

Legumes Translated (Translating knowledge for legume-based farming for feed and food systems) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 817634

Legumes Translated

Legumes Translated (Translating knowledge for legume-based farming for feed and food systems) is an international research and development project funded by the European Union through the Horizon 2020 Programme under grant agreement number 817634. The Legumes Translated research consortium comprises 17 partners in 9 countries.

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Summary

This report for a practice guide examines the practical experience of Legumes Translated actor groups' as well as research reports on the economic aspects of legumes production. The compilation of economic information allows the identification of competitive conditions and cost-effective practices. By looking at the economic value of legumes at the individual crop level, it is shown which factors determine the profitability and which current developments on feed and food market can strengthen the position of European-grown legumes. The comparative advantage is discussed and reflected with insights on legumes' competitiveness in various regions, showing legumes' competitive power to several break crops. Expanding the analysis to the level of crop rotations allows to integrate legumes' pre-crop effects and resulting resource benefits to farmers are described. The importance to go beyond conventional gross margin analysis is underlined with approaches to assess the economic performance of cropping systems that can prevent economic underestimation of legumes and reveal their real economic performance. Legume prices are also discussed within the context of their value for animal feeding which shows potential to improve their crop-level economic value and simple tools for calculating the feed value are provided. The positive externalities for society caused by legume cutlivation are also discussed and exemplary measures to value the environmental benefits are presented. Conclusions towards succesful legume production in Europe are drawn and discrepancies between production potentials and actual practice will guide the search for barriers at farm, value chain and sector level, which is also relevant information for policy makers.

Background

Considering statistics on crop production in Europe, it becomes obvious that grain legume production does not play a significant role. Compared to cereals which cover around 50% of the EU's arable land[1], all types of legumes take only a fraction of it. Despite the numerous environmental benefits provided by legumes and the increasing criticism on imported soybeans that is associated with deforestation and further environmental and social problems, legume cultivation is underrepresented in European farming systems. However, there is a positive trend over the last years due to policy changes and consumer demands (Figure 1). Field peas and faba beans are profiting from EU greening regulations, and soybeans are produced to meet a growing demand for protein for feed and food within the EU.

European farmers place their decisions on which crop to grow on agronomic and economic facts. Many farmers question the production of legumes due to costs and revenues. Is it worthwhile to cultivate legumes in Europe? This practice guide examines the economic drivers of current European legume production. Through a compilation of economic information at different levels, cost-effective practices and competitive conditions are identified and farmers' choices are retraced.

[1] EUROSTAT 2020. Crop production in EU standard humidity; dataset: apro_cpsh1

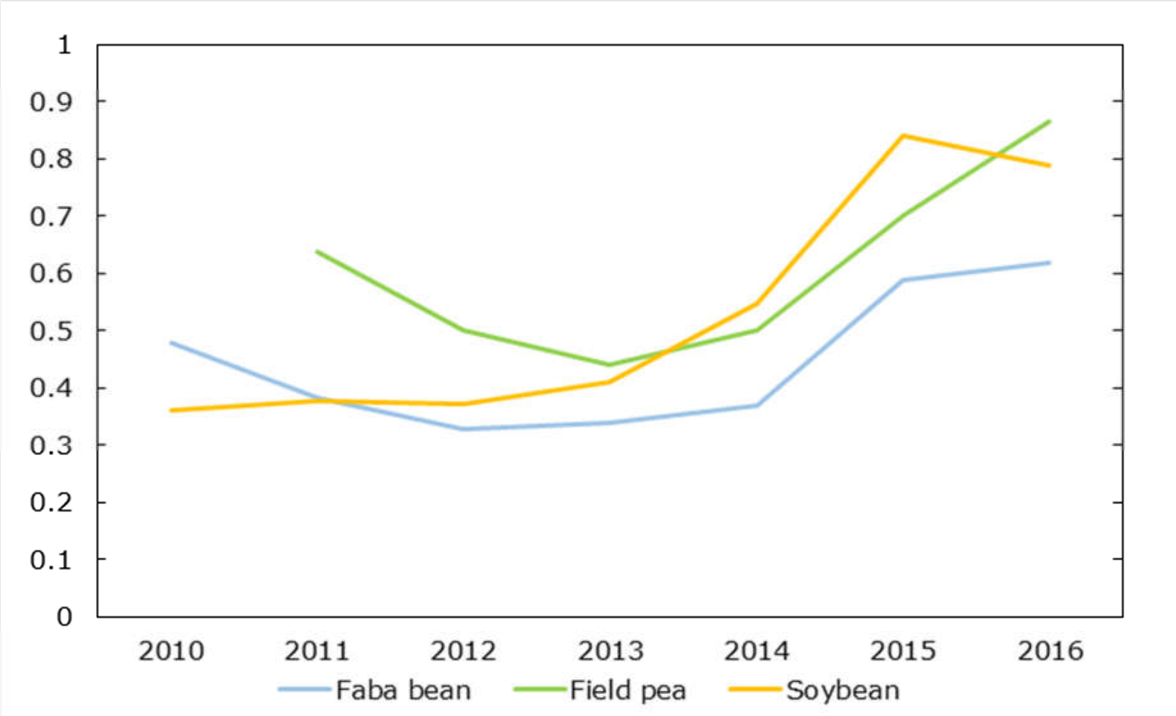

Figure 1 Area cultivated with field peas, faba beans and soybeans as a share (%) of EU arable land[1]

For this purpose, this guide integrates findings from previous projects and literature with valuable insights from the project partners of the EU-Horizon 2020 project Legumes Translated. Practical experiences on legume cultivation from different regions within the project' scope (Ireland, Germany, Serbia, Bosnia and Herzegovina, Finland) were analysed and related to general findings. As economic performance of legume crops differs across Europe depending on the regional conditions, diverse cases and legume crops were included.

Data and methods

Costs and revenues are impacted by a range of economic drivers and determine farmers' crop choices. Focusing on the farm level, yield and economic assessment data from the project partners and literature was compiled. The data set enclosed several levels of considerations. Yield and producer price data as well as cost structures of legumes and non-legume crops for comparison were gathered. Moreover, simple gross margins of legumes and non-legumes as well as gross margins taking into account the pre-crop value of legumes were included. The gross margins across legume-supported rotations and similar rotations excluding legumes were also compared.

Following from the composition of the gathered material the guide considered at first the crop-level profitability from legumes alone and then compared to other crops. Secondly, the pre-crop value of legumes was highlighted and estimations of its magnitude were illustrated. Thirdly, analysis at the rotation scale were considered and different concepts to approach the rotation-level profitability described. Subsequently, an economic evaluation of the feed value of legumes was done. Lastly, legumes' potential to contribute to societal benefits and mechanisms for an economic evaluation of these benefits were analyzed and demonstrated.

In all steps the determining factors were described and illustrated with the exemplary case regions from Legumes Translated. Based on the experiences within the actor groups of Legumes Translated[2], economic information was compiled in the form of primary and secondary data. Exemplary data from Ireland, Germany, Serbia, Bosnia and Herzegovina and Finland were considered.

Irish experiences on growing legumes were taken from the Teagasc eProfit Monitor (ePM) which is an online financial analysis tool available to all Teagasc clients.[3] Farmers together with their advisors can provide their financial and technical data in the financial benchmarking tool and track their performance. The input data are analyzed and comparisons between the main tillage crops across all farms are made and published in reports. Reports were included covering data from 2016 – 2018. The analyses are based on data provided by Irish crop farmers relating to the respective production year. About 340 farmers completed the Teagasc eProfit Monitor in all three years. Although all the farmers are self-selected and can be classified as progressive farmers, the reports offer valuable insight into Irish farmers' experiences on growing faba bean, other break crops and cereals.

Data on the profitability from pea and bean cultivation was gathered from reports of the 75 demonstration farms participating in the actor group "German Pea and Bean Network".[4] The project runs since 2016, covers 11 of the 16 federal states of Germany and is part of the German protein crop strategy.[5] It supports the cultivation and

[2] Actor groups are existing groups of farmers and other innovators that are the basis for the project's concept. Actor groups are already supported by public initiatives such as the German Plant Protein Strategy or private initiatives.

[3] Teagasc 2019. eProfit Monitor Analysis - Tillage Farms Crops Environment & Land Use Programme; 2016-2018; www.teagasc.ie/crops/crops/reports--publications/crops-margins--ecrops/

[4] "Exemplary demonstration network for expanding and improving cultivation and utilisation of peas and beans" www.demoneterbo.agrarpraxisforschung.de/

[5] www.bmel.de/EN/Agriculture/Plants/_Texte/Eiweisspflanzenstrategie.html

utilization of legumes in Germany, with a focus on peas and beans. Results of the economic assessment included pea and bean cultivation as well as comparison to regionally relevant other crops.[6]

Another project within the German protein crop strategy, the soybean network to improve the cultivation and utilization of soybeans in Germany, gathered data on the economic competitiveness of soybean. Over 110 farms were considered in the analysis and the crop years from 2014 to 2016 were taken into account.[7] Additionally, results from an exemplary area in Southern Germany show a comparison of simple gross margins of legumes and non-legume crops.[8] Moreover, primary data on soybean production compiled by the actor group "German Soybean Assocation" [9] was integrated.

Data on exemplary crop rotations with and without legumes in the German federal state of Brandenburg were collected by the "Brandenburg Farmers' Network" actor group.

Soybean production in Serbia as well as Bosnia and Herzigovina was represented by information from a report focusing on the economic aspects of soybean production across farms in main production regions in 2016.[10] The study identified gross margins in soybean production and included 39 Serbian farms and 23 farms in Bosnia and Herzegovina via surveys and interviews. Some of the farms were chosen by random choice and some were picked from a list provided by GIZ. Data on these South-Eastern European examples were provided by the actor group "Soybean Cultivation Group in South-Eastern Europe".

Finnish examples provided by the actor group "Ground for Growth" were enclosed with data input from the ProAgria's[11] Agricultural Plot database. The database compiles economic and biological data based on farming notes, yield analysis and financial calculations from farmers across Finland. Crops specific results in terms of net profits and losses were considered for 2018.

[6] Zerhusen-Blecher, P., Stevens, K., Schäfer, B.C., Braun, J. 2019. Wirtschaftlichkeit. Erbsen und Ackerbohnen – lohnenswerte Kulturen; www.demoneterbo.agrarpraxisforschung.de/fileadmin/user_upload/Bilder/Artikel_Wirtschaftlichkeit_2016_2017_190121.pdf.
[7] Wolf, L., Schätzl, R. 2017. Wettbewerbsfähigkeit der Sojabohne in der Praxis, in: LTZ 2017: Soja-Tagung 2017, 06.–07.12.2017, Rastatt Tagungsband, p. 40-41.
[8] LTZ 2018. Wertschöpfung durch heimische Sojabohnen Leitfaden für Anbau und Verwertung von gentechnikfreien Futtersojabohnen aus konventionellem Anbau.
[9] www.sojafoerderring.de
[10] Popović, R., Lovre, K., Djokic, D., Kleut, Z., Sekuljica, N., Prodanovic, R. 2016. Project: Gross margins calculation of non-GMO soybean production in Serbia and Bosnia and Herzegovina. Report for 2016.
[11] www.proagria.fi/en

Economic value of legumes at crop level

Current knowledge

In numerous economic reports and analyses, legumes' profitability was described as low and the small economic returns from marketed outputs were linked to the minor legume cultivation in Europe.[12] [13] [14] [15] [16] [17] Considering the two main factors for profitability – yield and price – several legume inherent characteristics and connected developments can explain these statements.

Yield instability and lower yield levels

Yields of grain legumes are volatile and fluctuations have a direct effect on the economic gains from grain legume production which is also the case for other spring crops.[18] The yield instability is caused by several agronomic factors, enclosing plant physiology, weather as well as technical matters.[19] For instance, some legume species are highly susceptible to weeds, pest and diseases.[20] Legumes' lack of stress resistance to poor growing conditions as water deficits during critical growth phases and the indeterminate growth habit lead also to lower yield stability compared to winter cereals.[21]

Besides volatile yields, the generally lower yield level of legumes compared to other crops in Europe – especially cereals – reduces the economic attractiveness of legumes considerably. While the yield potential of cereals has steadily increased, the changes in yield trends of legumes lag behind.[22] [23] Legume breeding efforts to overcome such adverse factors and aim for higher yielding were low in comparison to breeding investments in other crops. Especially such yield fluctuations can influence the subjective assessment of legumes as shown in surveys.[24] [25] [26] [27] As a result, risk-averse producers

[12] Magrini M.-B., Anton, M., Cholez, C., Duc, G., Hellou, G., Jeuffroy, M.H., Meynard, J.M., Pelzer, E., Voisin, A.S., Walrand, S. 2016. Why are grain-legumes rarely present in cropping systems despite their environmental and nutritional benefits? Analyzing lock-in in the French agrifood system. Ecological Economics 126, 152–162.
[13] 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.
[14] 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.
[15] Jouan, J., Ridier, A., Carof, M., 2019. Economic drivers of legume production: approached via opportunity costs and transaction Costs. Sustainability 11, 705.
[16] LMC International, 2009. Evaluation of measures applied under the Common Agricultural Policy to the protein crop sector, in: Main Report. LMC International, New York, Oxford, Kuala Lumpur; http://ec.europa.eu/agriculture/eval/reports/protein crops/.
[17] 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.
[18] 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.
[19] LMC International, 2009; see above.
[20] Bues A. et al. 2013; see above.
[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] Bues A. et al. 2013; see above.
[23] Watson, C., et al. 2017; see above.
[24] von Richthofen, J.-S., Pahl, H., Bouttet, D., Casta, P., Cartrysse, C., Charles, R., Lafarga,A. 2006. What do European farmers think about grain legumes. Grain Legumes, 14–15.
[25] Zimmer, S., Liebe, U., Didier, J.-P., Heß, J. 2016. Luxembourgish farmers' lack of information about grain legume cultivation. Agron. Sustain. Dev. 36, 2.

perceive legume cultivation as risky production and consequently avoid it. However, the scientific community has lately discussed the coherent attribution of yield instability to legumes and study findings pointed out that grain legume yields are not inherently less stable than yields of other spring-sown crops[28] and therefore yield volatility should not be overrated.

Price levels

While the level of yield is essential for the income from grain legume production, the price is equally important and was indicated as the third major obstacle for legume cultivation next to grain yield and unstable yields.[29] Achieving reasonable producer prices is essential for farmers, but the price level of legumes is impacted by several factors and a key role plays the market demand. Analyzing the currently most essential drivers for the market demand and distinguish thereby between food and feed markets allows to draw inferences on prices of European legumes.

At EU-level, data on price levels are only available for major crops such as wheat, rapeseed, soybean and to limited extent also for pea (Figure 2).

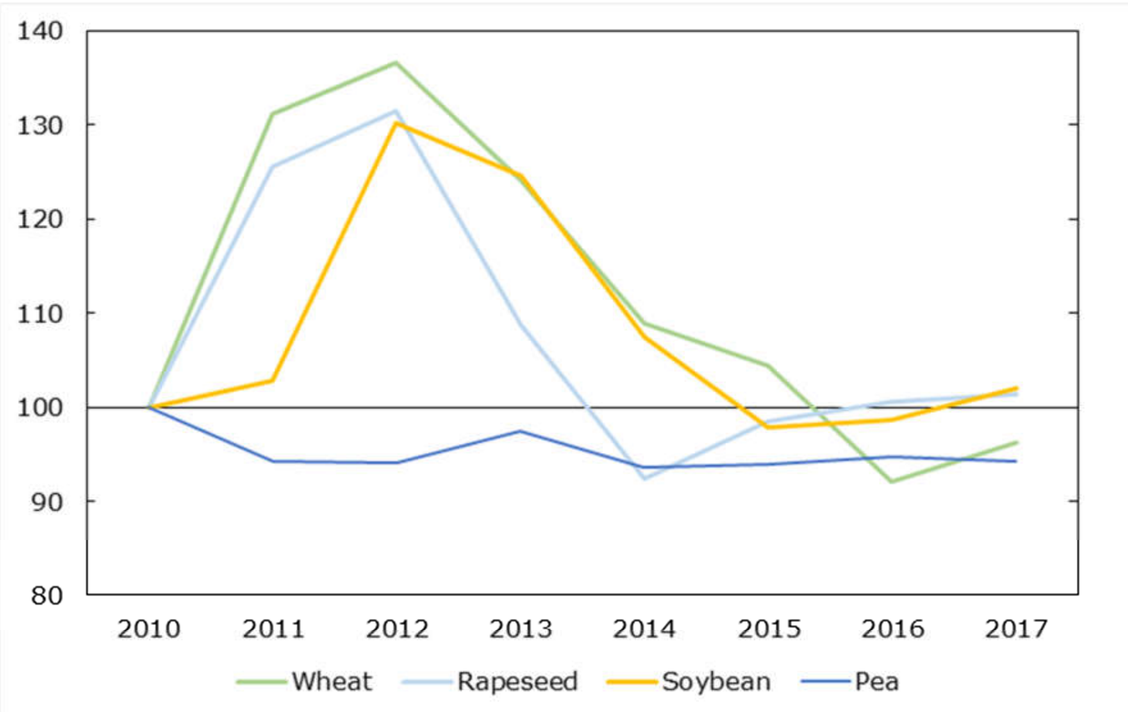

Figure 2 Price changes for wheat, rapeseed, soybean and pea relative to prices in 2010; deflated price indices for crops, EU-28, 2010–2017 [30]

[26] Reckling, M. 2020. Entwicklungen im Lupinenanbau: Ergebnisse einer online-Umfrage. Presentation at the GFL-Jahrestagung, Ruhlsdorf, 15.02.2020; http://lupinenverein.de/wp-content/uploads/2020/02/8_Reckling_Umfrage.pdf

[27] Jouan, J., Ridier, A., Carof, M., 2019. Economic drivers of legume production: approached via opportunity costs and transaction Costs. Sustainability 11, 705.

[28] Reckling, M. et al. 2018 Grain legume yields are as stable as other spring crops in long-term experiments across northern Europe. Agron. Sustain. Dev. 38, 63.

[29] von Richthofen, J.-S. et al. 2006. What do European farmers think about grain legumes. Grain Legumes, 14–15.

[30] Eurostat http://ec.europa.eu/eurostat/product?code=apri_pi10_outa&mode=view&language=en

The prices of wheat, rapeseed and soybean are strongly linked to the world market, whereas other legumes such as faba beans, peas and lupins are mostly traded at national or even regional level. On these markets, prices are mainly based on contracts, which cover fixed amounts to be traded, or are negotiated within highly varying demand and supply settings. Therefore, legume prices (except for soybean) often do not follow global trends, but are subject to direct interactions between producers and buyers. For example, the price increases induced by the 2019 summer drought for wheat were not realized for peas produced in Germany, although the yields for peas were also affected by the drought.[31]

Demand patterns

Europe's citizens cover their daily protein consumption with 59 % animal protein, 27 % of the protein is derived from cereals, 3.6% from vegetables and only 1.6 % from pulses.[32] Changes in dietary patterns led to this significantly higher consumption levels of animal proteins, particularly meat, resulting in an increased demand for grain legumes for feed.[33] European agriculture is not able to meet its requirements for protein feed and therefore imports 70% high-protein materials for livestock feed.[34] Next to the EU protein deficit, feed compounders also favor high volumes and homogenous qualities[35] offered by international traders with soybean products. Soya meal is also preferred because of its high protein content, amino acid composition and all year long availability.[36] These conditions have led to a risen demand for soybean and hence a steady price increase since 2007[37], which has stopped since 2012. Prices of imported soybean are closely correlated with prices of European grown legume grain that is used for animal feed and hence have also increased until 2012[38], a trend that has also stopped since then. As mentioned above, this is not the case for other grain legumes in Europe, for example peas (Figure 2), where prices stayed relatively stable over the past years.

Trade policies

Currently there are no import tariffs on the import of soybean and the majority of the imported soybeans are from genetically modified crops. Policies of the EU so far do not restrict GM (genetically modified) soybean for animal feed, but consumers are becoming more alert to GM products in feed[39], accordingly the demand for GM-free feed is rising. This increasing demand led to the emergence of a premium market segment for feed

[31] Zerhusen-Blecher, P., Stevens, K., Braun, J., Haberlah-Korr, V. 2019. Wirtschaftlichkeit des Anbaus von Erbsen und Bohnen; 5. Hessischer Leguminosentag, Hüttenberg, 10.12.2019; unpublished presentation.
[32] de Visser, C.L.M., Schreuder, R., Stoddard, F. 2014. The EU's dependency on soya bean import for the animal feed industry and potential for EU produced alternatives. Oilseeds and fats Crops and Lipids 21:D407.
[33] Zander, P. et al. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36,1–20.
[34] Watson, C., et al. 2017. Grain legume production and use in European agricultural systems. Adv. Agron. 144, 235–303.
[35] Zerhusen-Blecher, P., Kramps-Alpmann, D., Rohn, S., Braun, J., Schäfer, B. C. 2016. LeguAN – Innovative und ganzheitliche Wertschöpfungskonzepte für funktionelle Lebens- und Futtermittel aus heimischen Körnerleguminosen vom Anbau bis zur Nutzung (Arbeitspakete 2 und 7). Forschungsberichte des Fachbereichs Agrarwirtschaft Soest, Nr. 41.
[36] European Commission 2018. Report from the Commission to the Council and the European Parliament on the development of plant proteins in the European Union; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018DC0757
[37] Zander, P. et al. 2016; see above.
[38] Bues, A. et al. 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.
[39] European Commission 2018; see above.

with a substantial price premium for GM free products.[40] European-grown legumes could benefit through new economic opportunities from this development, as those are mandatorily GM-free and profit from increased prices.[41] Currently, European GMO-free soybeans have a 25-50 % price premium as compared to standard product.[42]

Conclusion from literature

Considering the above described numbers of protein intake shares, it becomes obvious that the feed market has a major role in comparison to the food market. Nevertheless, the food market has considerable potential in terms of profitability as legumes targeted for food markets can generally achieve higher prices than feed-targeted grain legumes.[43] Besides, the current development of the food market segment is very promising in light of double-digit growth and can no longer be categorized as a niche market.[44] Legumes can economically benefit from new outlets supported by food innovations.[45] Through novel processing techniques a range of new products is introduced and especially the market for meat and dairy alternatives has great potential.[46] European-grown legumes could also exploit consumers' interest and awareness in regional origin as well as environmental performance of products through labelling schemes and achieve thereby higher prices.[47]

Keeping these general considerations of major drivers for economic profitability in mind, exemplary numbers from the case studies were analysed. Here we examined single elements – yield, price and cost structures - and gross margins, the most common indicator for economic evaluation at the crop level.

Yield and gross margins reported by project partners

Among the project partners of Legumes Translated, data on yield and gross margins were gathered at different times, scopes and project levels. This information is not directly comparable, but it provides a range of orientation on what can be achieved in legume production (Table 1).
A very informative source is the Teagasc dataset based on a benchmarking tool for Irish farmers. In Ireland, faba beans reach the highest yield levels and solid gross margins. Other legumes play no significant role in this region.

In Germany, the German Pea and Bean Network reports average yields and gross margins for faba beans and peas, both for conventional and organic production systems all over Germany. The numbers show the advantage of organic systems that compensate

[40] European Commission 2018. Report from the Commission to the Council and the European Parliament on the development of plant proteins in the European Union; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018DC0757
[41] Zander, P. et al. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36,1–20.
[42] DonauSoja 2020: DS/ES Sojaschrot Preis; https://www.donausoja.org/de/dses-sojaschrot-preis/
[43] 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.
[44] European Commission 2018; see above.
[45] Magrini M.-B. et al. 2016. Why are grain-legumes rarely present in cropping systems despite their environmental and nutritional benefits? Analyzing lock-in in the French agrifood system. Ecological Economics 126, 152–162.
[46] European Commission 2018; see above.
[47] Zander, P. et al. 2016; see above.

lower yields with higher prices, which reflects in much higher gross margins as compared to the conventional systems.

Table 1 Yields and gross margins from project results or specific benchmarking networks; conventional and organic systems

Country	Crop	Yield t/ha	GM €/ha*	Time period	Source
Ireland	Faba bean conventional	5.4	517	2016-2018	ecrop
Germany	Faba bean conventional	4.4	257	2016-2018	DemonetErBo
	Faba bean organic	3.0	642	2016-2018	DemonetErBo
	Pea conventional	3.9	165	2016-2018	DemonetErBo
	Pea organic	2.4	483	2016-2018	DemonetErBo
	Soybean conventional	2.7	347	2014-2016	German Soy Network
	Soybean organic	2.3	1327	2014-2016	German Soy Network
	Soybean conventional *Loess* no irr.	3.6	379	2015-2018	AG German Soybean Assoc.
	Soybean conventional *Gravel* irrig.	3.0	83	2015-2018	AG German Soybean Assoc.
Finland	Faba bean conventional	2.2	-155 (Ø 2017-2018)	2009-2018	Yields LUKE GM proAgria
	Pea conventional	2.4	86 (2018)	2009-2018	Yields LUKE GM proAgria
Serbia	Soybean conventional	4.5	820	2016	University Novi Sad
	Soybean organic	3.9	1602	2016	University Novi Sad
Bosnia and Herzegovina	Soybean conventional	3.7	620	2016	University Novi Sad

*GM corrected by the pre-crop value which is assumed by some study authors. GM includes only legume specific subsidies, but no general EU-CAP-area payments

Besides faba bean and pea, soybean cultivation becomes more and more important in Germany. The results from conventional soybean production from the German soybean network show an average gross margin of 347 €/ha in the years 2014-2016.[48] This makes soybean in most cases a more profitable crop than other legumes. Even though the conventional soybean yields were on average 17% higher than organic yields, organic soybean production achieved significantly higher gross margins with over 1,327 €/ha. Also here, the higher returns from organic production schemes were mainly caused by the noticeably higher prices. Organic soybean prices are often more as twice as high than the conventional ones.

Data on soybean production from one of the actor groups within Legumes Translated – the German Soybean Association - showed soybean gross margins from two sites in the Southwest of Germany (*Markgräflerland*). One site is characterized by the fertile soil type *Loess*, while the other site had a gravel subsoil with little water capacity and low fertility, which needs irrigation for crop production. On the more favourable site the gross margin was significantly higher and comparable to the results from the Soybean network whereas the gross margin from the less favourable site was low with only 83 €/ha due to lower yields and irrigation costs.

In Finland, long term average yields for faba beans are around 2.2 t/ha, but the average gross margins available for 2017-2018 are negative due to higher production costs than

[48] Wolf, L., Schätzl, R. 2017. Wettbewerbsfähigkeit der Sojabohne in der Praxis, in: LTZ 2017: Soja-Tagung 2017, 06.–07.12.2017, Rastatt Tagungsband, p. 40-41.

revenue achieved. For peas, the long term average yields are 2.4 t/ha, with a positive gross margin in 2018.

Project data from demonstration farms both in Serbia and in Bosnia and Hercegovina show overall high yields and high gross margins, showing the influence of adequate climatic conditions and low production costs.

Looking at the detailed yearly results of pea and faba bean for the German case, it shows the variation of gross margins over the three consecutive years (Figure 3). For faba beans, both conventional and organic systems suffered extremely from the 2018 summer drought, with only around half of the gross margin achieved as compared to the preceding years. For peas, this effect was only visible for organic farming, while the conventional gross margins did not drop as drastically. Overall, organic legumes achieved a much higher gross margin in comparison to the conventional ones.

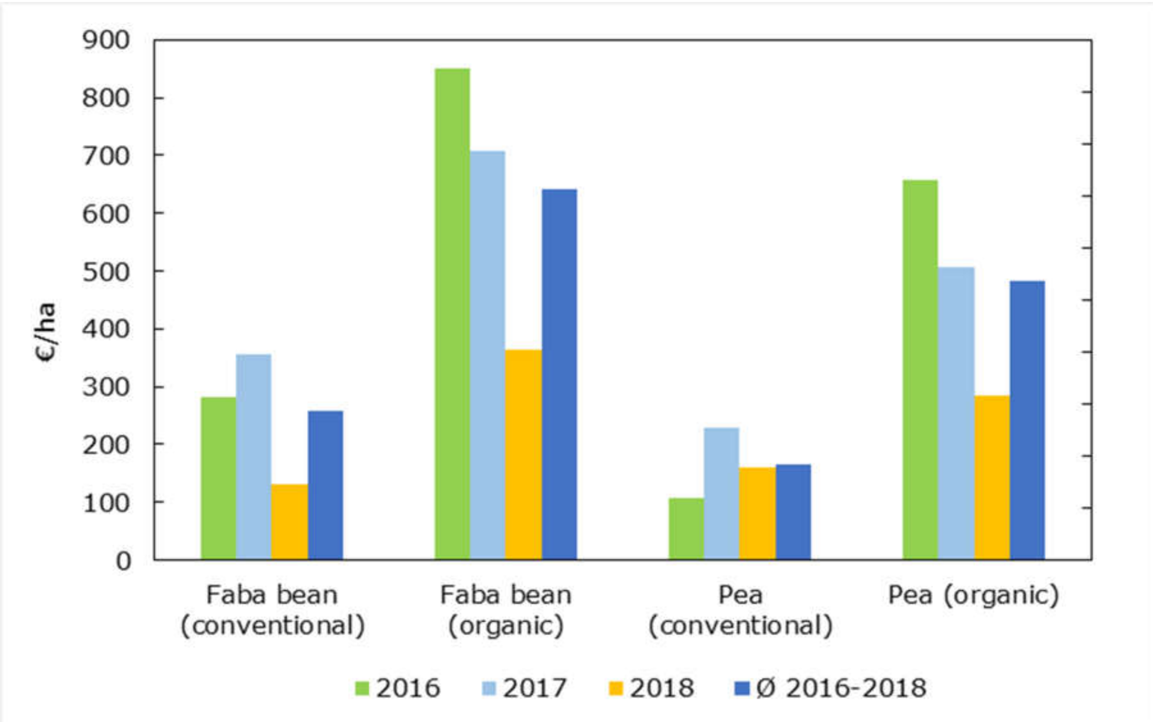

Figure 3 Gross margins for faba bean and pea; conventional and organic systems in German farms

The data of Serbia and Bosnia and Herzegovina allows a view into the structure of the resulting gross margins (Figure 4), which are rather outstanding compared to the other data sets. For all three groups the variable costs are comparably low, but given the high yields and good prices the revenues are very high which results in such high gross margins.

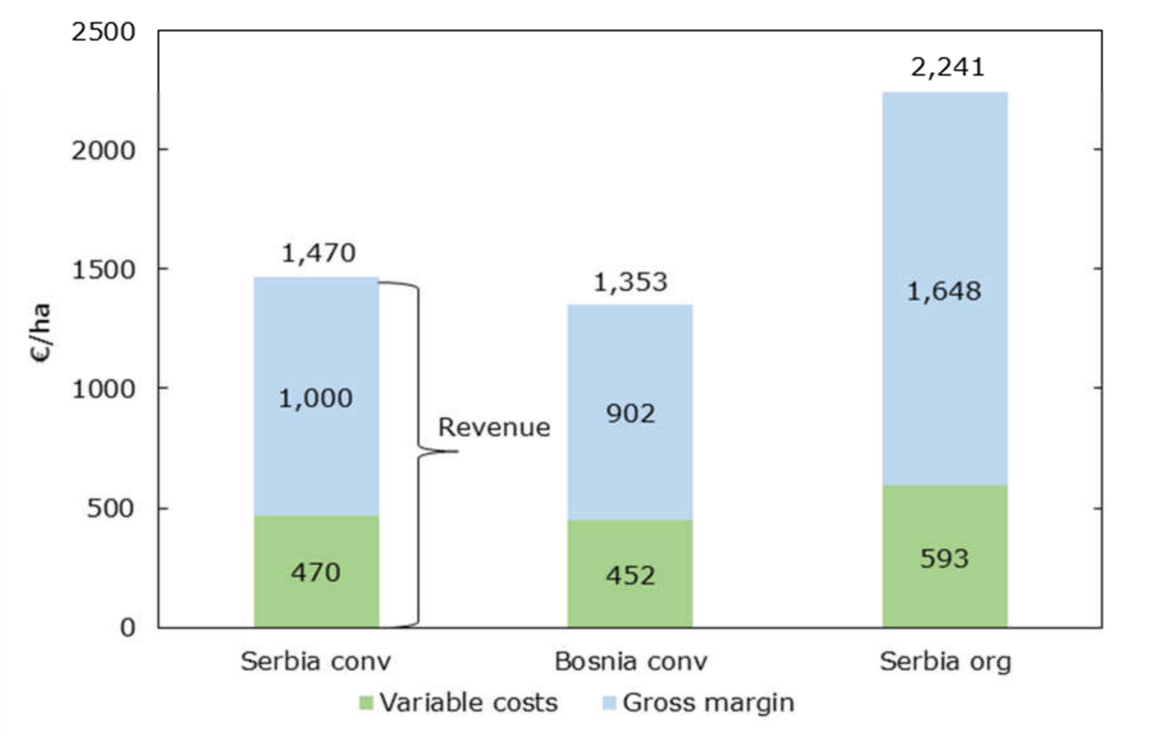

Figure 4 Revenue, gross margin and variable costs for soybean from demonstration farms in Southeast Europe

Competitiveness of legumes

Current knowledge

Farmers make their crop choices in consideration of competitive power of different crops – hence it is important to analyze the economic returns of legumes in comparison to other crops in detail. As mentioned above, other crops such as winter cereals seem to be a much more attractive crop choice due to their higher yield potential and lower production risks than legumes.

Several factors such as former policies on price support for cereals, lower breeding efforts in legume and non-legume crops or easily available nitrogen fertilizers connected to high production intensity have led to a differentiation and competition between cereals as major species and grain-legumes as minor species.[49] This dichotomy is characterized through a comparative advantage in the production of cereal crops in Europe over the production of European-grown legumes.[50] Using the land to grow wheat instead of legumes seems more profitable. Hence, the opportunity costs – the benefits of non-legume alternatives that are forgone through the legume cultivation – can be high.[51] Opposing or limiting factors to this very disadvantageous description of legumes' competitiveness at crop level, are the selection of suitable comparisons to legumes and a

[49] Magrini M.-B. et al. 2016. Why are grain-legumes rarely present in cropping systems despite their environmental and nutritional benefits? Analyzing lock-in in the French agrifood system. Ecological Economics 126, 152–162.

[50] Bues A. et al. 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.

[51] Jouan, J., Ridier, A., Carof, M., 2019. Economic drivers of legume production: approached via opportunity costs and transaction Costs. Sustainability 11, 705.

slight reduction of the comparative advantage of cereals over grain legumes due to improved competitive conditions in recent years.

Above we described that the typical comparison of legumes with profitable cereals as wheat or generally the most profitable crop of a region is inappropriate.[52] [53] Legumes should be compared to crops with average profitability or with a similar agronomic role in the crop rotation.[54] Other break crops such as sunflower, rapeseed or oat have resembling rotational crop effects and can therefore be particularly competing with legumes. Preissel et al. illustrated in a comparison of gross margins from grain legumes with alternative crops in Europe that grain legumes could rather compete with less profitable cereals as barley, rye or maize than with wheat or rapeseed or sunflower.[55] Competitive advantage of non-legume crops in terms of stable incomes connected to yield stability also needs to be carefully considered. A review showed that fluctuations of yield and gross margins are rarely notable higher than of other crops.[56] Furthermore, Reckling et al. could show that grain legumes' yields are not less stable than those of other spring crops and that grain legumes' yield performance often is negatively impacted though cultivation on less favorable sites.[57]

Beside adequate comparisons, changing competitive conditions makes the comparisons of legumes to other crops more advantageous. The above described price development of legumes, led to a faster price increase of protein crops than of wheat, resulting in a decreasing price advantage of wheat.[58] Besides, fertilizer prices are steadily increasing.[59] These changes reduce the comparative advantage of wheat or generally cereals over legumes.[60]

Details from project partners

Faba bean is the most relevant grain legume in Ireland. Comparing the returns of spring beans with the principal Irish tillage crop winter barley and other break crops, shows that the economic performance of spring beans is lower than of the other crops except for spring rapeseed (Figure 5). The gross margin of spring beans accounted in the average of 2016 to 2018 for 517 €/ha including the protein payment. The Irish Protein Aid Scheme was introduced in 2015 with a rate of 280 €/ha which is annually adjusted. Winter barley had an average gross margin of 879 €/ha. Even with the inclusion of the protein payment, spring beans were not competitive at all to this return. However, as described above, the typical comparison of legumes with the most profitable crop of a region is not always suitable and crops with a similar agronomic role should be compared. Considering the other break crops, winter oats performed best with a gross

[52] Zander, P. et al. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36,1–20.
[53] Preissel, S. et al. 2015. Magnitude and farm-economic value of grain legume pre-crop benefits in Europe: a review. Field Crops Res. 175, 64–79.
[54] Zander, P. et al. 2016; see above.
[55] Preissel, S. et al. 2015; see above.
[56] Preissel, S. et al. 2015; see above.
[57] Reckling, M. et al. 2018. Grain legume yields are as stable as other spring crops in long-term experiments across northern Europe. Agron. Sustain. Dev. 38, 63.
[58] Bues A. et al. 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.
[59] European Commission 2019. Fertilisers in the EU. Prices, trade and use. EU Agricultural Markets Briefs No 15; https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/farming/documents/market-brief-fertilisers_june2019_en.pdf
[60] Bues A. et al. 2013; see above.

margin of 704 €/ha. The generally lower returns from all spring sown crops might be reflecting the lower yields due to the summer drought in 2018. In comparison to spring rapeseed, spring beans could be competitive. The differences to spring oats and winter rapeseed are below 100 €/ha.

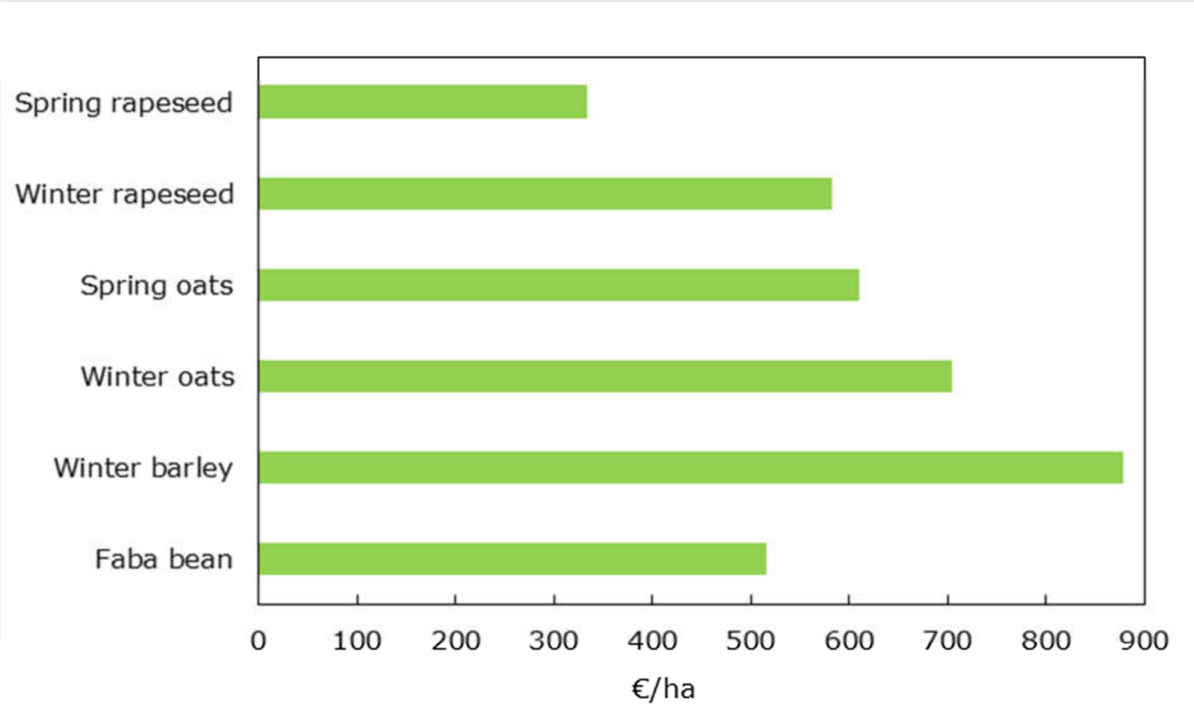

Figure 5 Gross margin of main crops in Ireland (Ø2016-2018)[61]

Considering the data from Finland the traditional legume crops - pea and faba bean – are compared with various main crops. Figure 6 shows the net profits and net losses of different crops for the year 2018. The most profitable crop was sugar beet with a gross margin of over 400 €/ha. Barley is the most produced cereal crop in Finland and feed barley achieved an average gross margin of 115 €/ha whereas the gross margin of malting barley was only 28 €/ha. Wheat, rye and oat are other cereal crops that are in wide-scale production. Conventional wheat recorded net losses, while conventional oat and rye could achieve gross margins of 56 €/ha and 104 €/ha respectively. Organically produced crops could benefit from higher prices and achieve higher returns. Faba bean production resulted in a negative gross margin of -135 €/ha. This gross margin deficit as well as deficits from other crops could be caused by the summer drought in the respective year which affected agricultural production substantially. But in consideration of the gross margins of faba beans from 2017 (Table 1) it is unlikely that the deficit can only be ascribed to the exceptional summer drought of 2018. Hence, the competitive power of faba beans is minor in the example considered. The gross margin of pea, however, accounted for 86 €/ha and can therefore be seen as competitive with more than half of the shown crops. Moreover, the gross margins of feed barley, organic spring wheat and rye were not more than 18-29 €/ha higher than the gross margin of pea.

[61] Teagasc 2019. eProfit Monitor Analysis - Tillage Farms Crops Environment & Land Use Programme; 2016-2018; www.teagasc.ie/crops/crops/reports--publications/crops-margins--ecrops/

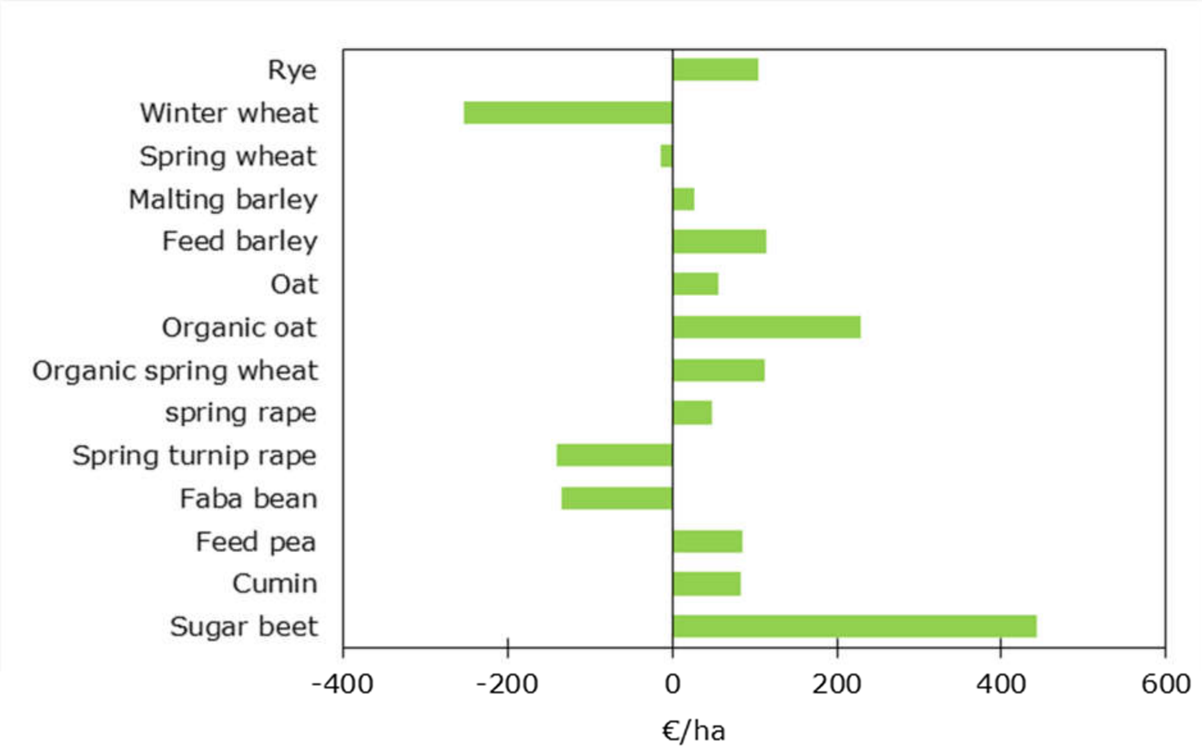

Figure 6 Gross margins of main crops in Finland 2018

Beside these analysis of legumes' competitiveness from Irish and Finnish data, Figure 7 illustrates the competitiveness of pea in comparison to wheat and maize and faba bean compared to wheat and rapeseed based on data from exemplary farms in Germany. In this project an extended gross margin (eGM) calculation was applied that includes, besides revenue and direct variable costs of production, also the labour and machinery requirements as well as a monetary estimation of pre-crop value (see section on pre-crop benefits). Considering the differences of the applied method which attached a considerable benefit to the pre-crop value, it shows that faba beans were competitive to wheat in 2016 and 2017. The eGM was 175 €/ha and 321 €/ha higher in the years respectively. Compared to rapeseed, faba bean was only competitive in 2017 with a eGM advantage of 174 €/ ha. Pea had a slightly higher eGM in the years 2016 and 2017 compared to wheat. The differences of 31 and 23 €/ha, however, are very small and if the pre-crop value was not taken into account, the legume crop would not be competitive. Comparing pea to maize, shows that the eGM of maize was significantly higher in 2016 and 2017. In 2018 the difference was also negative for pea, having a 86 €/ha lower eGM than maize.

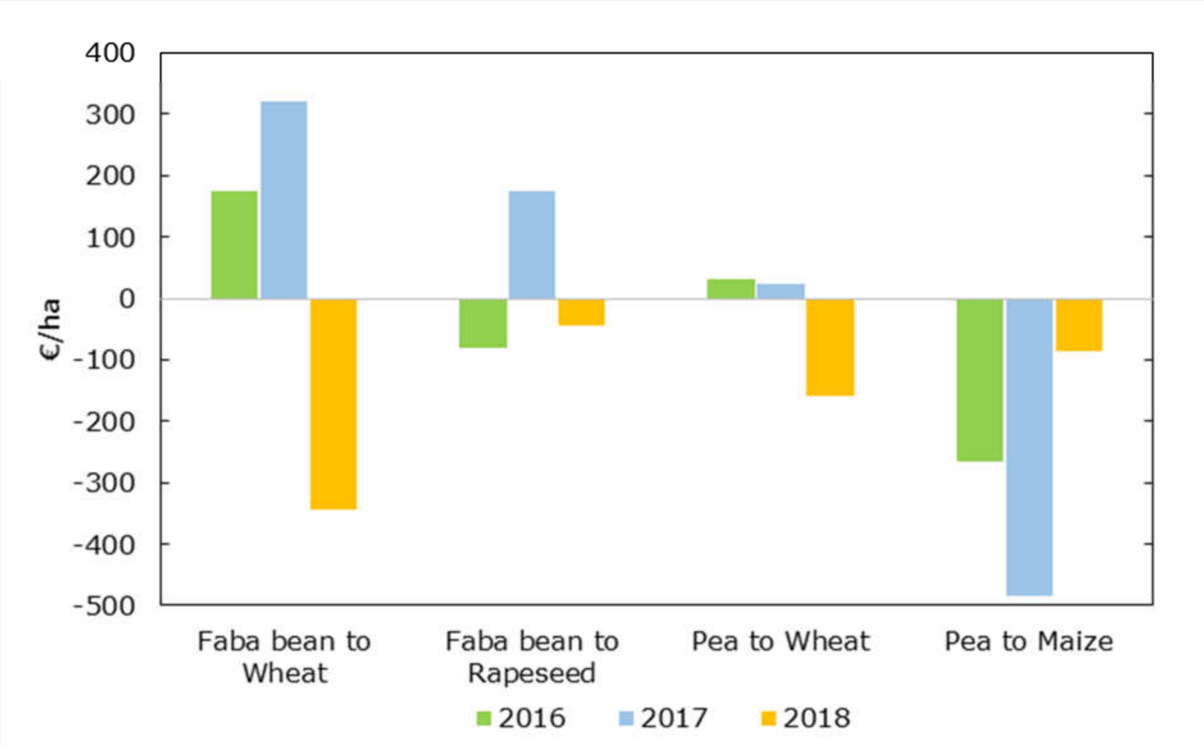

Figure 7 Differences of extended gross margins of pea and faba bean and comparison crops[62]

While the comparison of faba bean and pea with other crops showed a diverse picture in terms of legumes' competitiveness, an analysis of soybean production compared to other crops' production leads to more advantageous results. Exemplary data from an area in Southwest Germany illustrates differences in gross margins of conventional winter wheat, maize, pea and soybean (Table 2).

Considering soybean production in comparison to the other crops shows that soybean are rather cost-effective and extensive crops. The average soybean price from 2013-2017 were 400 €/t and this high price level of soybean enabled high revenues that are comparable to those of winter wheat and maize. The price of pea with 200 €/t was only 50% than that of soybean, but 50 €/t higher than those of winter wheat and maize. Nevertheless, this price difference could not compensate for the lower pea yields and caused the low revenue. Both legume crops had significantly lower fertilizer costs and the total variable costs were also considerably lower. Soybean achieved with 352 €/ha a higher gross margin than winter wheat, only maize returns were 100 €/ha higher. The gross margin of pea was the lowest with 140 €/ha.

[62] Zerhusen-Blecher, P. et al., 2019. Wirtschaftlichkeit des Anbaus von Erbsen und Bohnen; 5. Hessischer Leguminosentag, Hüttenberg, 10.12.2019; unpublished presentation.

Table 2 Comparison gross margins of soybean with winter wheat, maize and pea; conventional farms in Oberrheingraben, 2013-2017[63]

Crop		Winter wheat	Maize	Pea	Soybean
Yield Oberrheingraben Ø 2013– 2017	t/ha	7,6	10,4	3,6	2,8
Price Ø 2013– 2017	€/t	150	150	200	400
Revenue	€/ha	1,110	1,554	720	1,109
Subsidies	€/ha	270	270	270	270
Revenue incl. subsidies	€/ha	1,380	1,824	990	1,379
Costs of seed	€/ha	103	143	140	240
Total costs of fertilizer	€/ha	238	275	36	60
Costs of crop protection	€/ha	189	78	68	95
Variable costs of machinery	€/ha	102	130	109	109
External services	€/ha	138	157	160	160
Other costs (without interest)	€/ha	88	326	67	98
Interest rate	€/ha	8	7	4	5
Total variable costs[1]	€/ha	858	1,109	584	762
Gross margin without subsidies[2]	€/ha	260	452	140	352
Gross margin incl. subsidies[2]	€/ha	530	722	410	622

[1] Costs referreing to calculation data cash crop 2018 without VAT, resp. time series 2016-2018

[2] Gross margins without interest rate

Conclusion on crop competitiveness

Competitiveness of crops are a crucial factor for farmers' crop choices. Legumes' competitive power was often described as low and considerations of the results from the above analyzed examples showed a mixed picture. Legumes were in no case competitive with the most profitable crop of a region. However, the profitability of faba bean in Ireland and Germany and the returns of pea in Finland and Germany were shown to be competitive in comparsion with less profitable crops. Soybean was shown to be even competitive with winter wheat.

Cost structures

The economic success of crop production is a function of revenue (yield harvested x crop price) and costs (fixed and variable costs). The gross margin is the result of revenue minus the variable costs. Above we described gross margins of different legumes and other crops, but the actual variable costs were not further distinguished. Low variable costs avoid that farmers have to pay high amounts of cash for inputs that increase the risk of financial losses in case of crop failure. Project data from the German Pea and Bean Network highlights the differences between legumes and cereals (Figure 8). This example also includes fixed costs, mainly machinery costs, in the calculation. While seeds are slightly more expensive for legumes, the low amount of fertilizer costs is the typical asset

[63] LTZ 2018. Wertschöpfung durch heimische Sojabohnen Leitfaden für Anbau und Verwertung von gentechnikfreien Futtersojabohnen aus konventionellem Anbau.

of legumes. But also costs for pesticides, machinery and labour are lower for faba beans and peas as compared to cereals.
A similar pattern can be found for Ireland: the Teagasc data set[64] reveals that both material and machinery costs are lower for spring (faba) beans compared to all other main crops (Figure 9). Low input costs can ease the farm's financial liquidity over the year by avoiding high spendings on farming inputs.

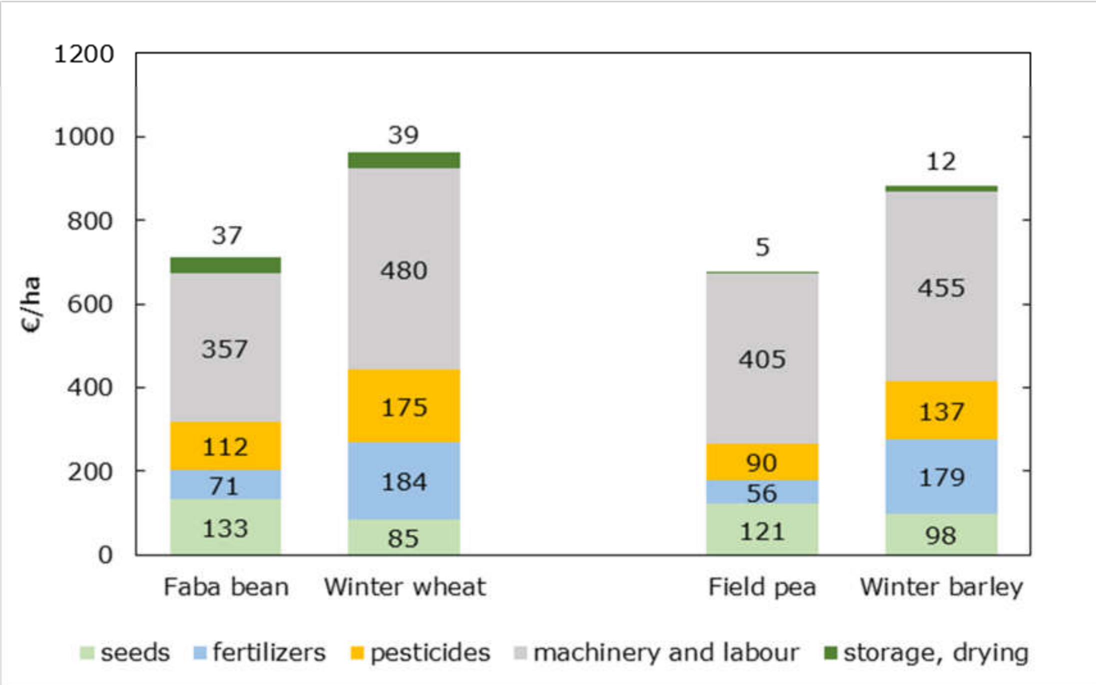

Figure 8 Cost structures for faba bean and pea in comparison to other crops in the German Pea and Bean Network[65]

Cost structures for the production of the same crop can also vary to some extent. Project data from Serbia and Bosnia and Herzegovina[66] show differences in fertilizer, fuel and machinery costs for the production of conventional soybean between the two countries (Figure 10). The cost structure for organic soybean differs drastically in terms of total amount and cost components. Obviously, there are no costs for pesticides, but machinery costs are much higher for the organic production.

[64] Teagasc 2019. eProfit Monitor Analysis - Tillage Farms Crops Environment & Land Use Programme; 2016-2018; www.teagasc.ie/crops/crops/reports--publications/crops-margins--ecrops/
[65] Zerhusen-Blecher, P. et al., 2019. Wirtschaftlichkeit des Anbaus von Erbsen und Bohnen; 5. Hessischer Leguminosentag, Hüttenberg, 10.12.2019; unpublished presentation.
[66] Popović, R. et al. 2016. Project: Gross margins calculation of non-GMO soybean production in Serbia and Bosnia and Herzegovina. Report for 2016.

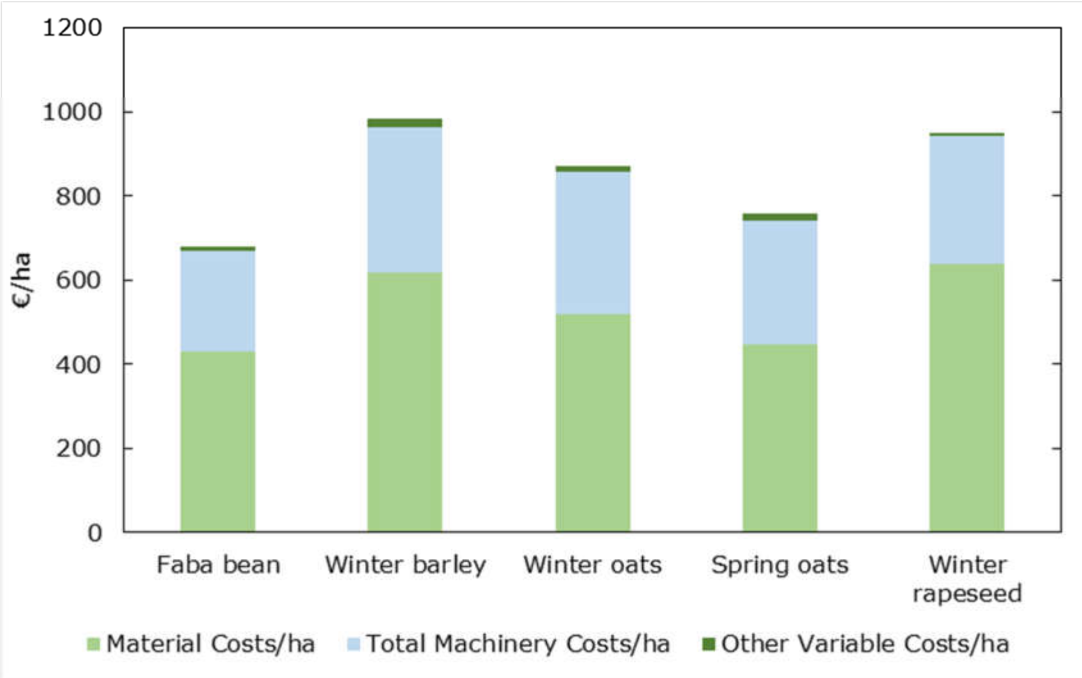

Figure 9 Cost structure for main crops grown in Ireland

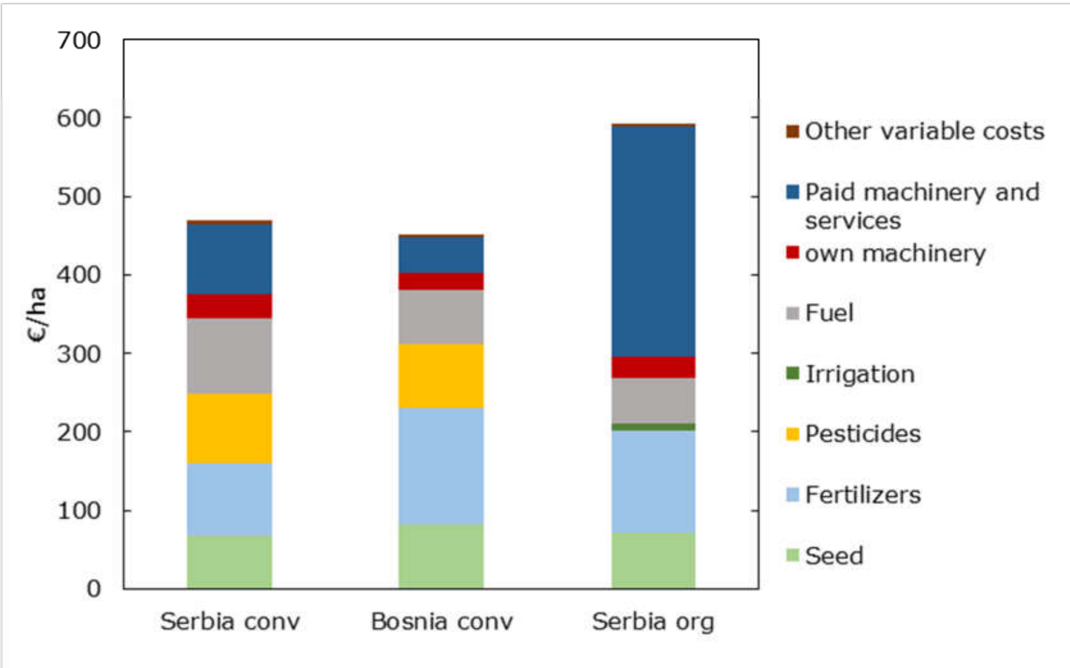

Figure 10 Cost structures in soybean production under conventional and organic production systems in Serbia and Bosnia and Herzegovina[67]

Overall, production costs play a decisive role for a profitable production of legumes. Keeping costs low, while yields increase through advances in practical knowledge and progress in breeding, can improve the chances of legumes gaining a higher market share.

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[67] Popović, R. et al. 2016. Project: Gross margins calculation of non-GMO soybean production in Serbia and Bosnia and Herzegovina. Report for 2016.

Pre-crop benefits of legumes

Although grain legumes' competitiveness compared to other crops appeared in some instances disadvantageous in the previous section, the cost-effectiveness increases when the pre-crop value is taken into account. The economic valuation of legumes' contribution to the following crops in the cropping system is essential in order to get a realistic picture of their competitiveness.[68]

Legumes' pre-crop effect offers several agronomic benefits that are caused by the crops' biology and the applied production techniques.[69] Two elements have been ascribed to the pre-crop effect – the break-crop effect and the nitrogen effect.[70]

The nitrogen effect refers to legumes' special ability to fix atmospheric nitrogen in a symbiosis with a bacterium. This biological nitrogen fixation provides the legume crop itself with nitrogen so that no or only little nitrogen fertilizer is required. The need for nitrogen fertilization in the subsequent crops is also decreased by nitrogen in the crop residue that is available to subsequent crops.[71] How much nitrogen is fixed depends on several factors as legume species, temperature or water availability.[72]

The break crop effect is not legume-specific but can also be achieved by other break crops as for example sunflower or oat that have positive effects on monotonous crop sequences through diversification.[73] By breaking cycles of soil-borne diseases and diminishing pressure from weeds and pests, the potential of pests, diseases and weeds is reduced and less pesticides are needed.[74] Soil organic matter content and soil structure as well as water-absorbing capacity are also positively influenced and issues such as soil erosion can be reduced.[75] Moreover, legumes are able to use reserves of phosphorus in the soil and affect the phosphorus availability to subsequent crops.[76]

Nitrogen and break crop effect combined offer various resource benefits to farmers and result in an increased yield of subsequent crops. Zander et al. conceptualized pre-crop effects as "non-market outputs" of legumes and showed the need to translate those into economic terms.[77] However, the individual benefits are partly difficult to quantify in economic terms.[78] Basically, they can be captured in cost saving effects and increased revenues.[79] Input requirements are decreased through the above described internal

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[68] Preissel, S. et al. 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.
[69] Legume Futures 2014. Legume-supported cropping systems for Europe. General project report; www.legumefutures.de
[70] Chalk, P.M. 1998. Dynamics of biologically fixed N in legume-cereal rotations: a review. Aust. J. Agric. Res. 49, 303–316.
[71] Bues A. et al. 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.
[72] Watson, C., et al. 2017. Grain legume production and use in European agricultural systems. Adv. Agron. 144, 235–303.
[73] Legume Futures 2014; see above.
[74] Bues A. et al. 2013; see above.
[75] Bues A. et al. 2013; see above.
[76] Watson, C., et al. 2017; see above.
[77] Zander, P. et al. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36,1–20.
[78] Zander, P. et al. 2016; see above.
[79] Preissel, S. et al. 2015. Magnitude and farm-economic value of grain legume pre-crop benefits in Europe: a review. Field Crops Res. 175, 64–79.

effects. Fertilizer and pesticide savings as well as reduced or zero tillage systems define the cost reduction potential.[80] [81] Increased revenues are caused by increased yields in subsequent crops. The extent of the yield benefits are dependent on the reduction of nitrogen fertilizer.[82] If nitrogen fertilization is significantly reduced in the subsequent crop, the yield benefit is smaller, but if nitrogen fertilization is kept at the same level as without legumes, the yield benefit can be raised to highest levels.[83]

Practically translating the conceptualized economic rewards from legume cultivation often means to deduct the additional value in the gross margin of the following crop and add it to the legume's gross margin. This requires to estimate the size of the cost savings as well as the additional incomes. Estimations of these values vary significantly in literature and it also needs to be taken into account that they differ depending on the alternative crop chosen for comparison.[84] This showed that yield benefits in cereal crops following legumes compared to following cereals can be estimated between 500 to 1,600 kg/ha applying a moderate fertilization level in temperate European conditions. The yield benefit in comparison to broad-leaved pre-crops was with moderated fertilization levels smaller and accounted for 100-400 kg/ha. In Mediterranean conditions legumes' pre-crop effect was also smaller and yield increases of 200 kg-1500 kg/ha in following cereals were found. Applying the current prices of the following cereals, a monetary value can directly be assigned to the yield increases.

Considering the components of the cost reduction potential - fertilizer and pesticide savings and reduction in tillage costs – an overall smaller economic benefit in comparison to the increased revenue can be derived. Nitrogen fertilizer savings were estimated to account for 23-31 kg per hectare without any yield losses.[85] However, farmers do not always decrease the applied fertilizer amounts in the subsequent crop. Therefore, this resource benefit is often not fully exploited.[86] While reduced nitrogen fertilization and yield increases are mostly covered in economic analysis of legumes' pre-crop value, reduced tillage costs and pesticide savings are less frequently considered.[87] Cost reduction potential through pesticide savings were estimated up to 50 €/ha. An even higher reduction potential of 70-125 €/ha was ascribed to reduced tillage systems when besides fuel costs also decreased fixed costs for machinery endowment and labour costs were enclosed.[88]

According to the literature review, the total economic value of the pre-crop effect was in a range between 130-560 €/ha. In the Legume Futures case studies it was between 106-296 €/ha.[89]

[80] Preissel, S. et al. 2015. Magnitude and farm-economic value of grain legume pre-crop benefits in Europe: a review. Field Crops Res. 175, 64–79.
[81] Effects through phosphorus mobilization are neglected in economic analysis as the mobilized amounts are small and varying (Zander, P. et al. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36,1–20.).
[82] Preissel, S. et al. 2015; see above.
[83] Preissel, S. et al. 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.
[84] Preissel, S. et al. 2015; see above.
[85] Preissel, S. et al. 2015; see above.
[86] Bues A. et al. 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.
[87] Preissel, S. et al. 2015; see above.
[88] Preissel, S. et al. 2017; see above.
[89] Preissel, S. et al. 2017; see above.

Considering exemplary data from the German Pea and Bean Network, farmers' estimations of the total pre-crop value are also in these ranges (Table 3). A survey with conventional farmers in the years 2016-2018 allowed to compile monetary estimations on several elements of the pre-crop effect (yield benefit, nitrogen fertilizer savings and savings in tillage activities). As a major factor the increased yield of the following crops leading to an additional revenue impacted the total pre-crop value. Around 70% of the total pre-crop value were caused by the additional revenue for both crops. Nitrogen fertilizer savings were estimated about 30 kg/ha what reflects also the findings from the discussed literature review. Saving due to reduced tillage activities were higher estimated for faba bean than for pea. The total pre-crop value of faba bean with 168 €/ha were also significantly higher than the total pre-crop value of pea with an estimation of 120 €/ha.

Table 3 Farmers' estimation on average pre-crop value of faba bean and pea compared to cereal pre-crop in conventional farming (2016-2018)90

	Faba bean	Pea
Additional reveneue of crop rotation (€/ha)	117	86
Additional yield of following crop (cereal unit/ha)*	7.0	5.3
N savings (kg/ha)	29	30
N savings (€/ha)	21	22
Savings in tillage activities (€/ha)	30	12
Total pre-crop value (€/ha)	168	120

* One cereal unit is equivalent to an energy content of 100 kg barley

Legumes in crop rotations

Following the rationale from the analysis of the pre-crop value of legumes, a consideration of legume-based crop rotations can support a more reliable examination of their profitability. Reviews on economic performance of rotations with legumes compared to rotations without legumes have shown that legumes can be economically attractive at the rotation scale.[91] [92] 35 out of 53 grain legume crop rotations were found to be competitive to non-legume rotations in Preissel et al..[93] Jouan et al. concluded that legumes have zero or negative opportunity costs considering the rotational scale.[94]

Suitable approaches for analyzing and comparing legume and non-legume based rotations are essential in this context and there are different concepts to approach the rotation-level profitability. Analysis from the research project Legume Futures were based on a cropping system assessment framework that systematically generated and assessed rotations with and without legumes for five European regions.[95] The approach was to consider regional-suitable crop rotations with and without legumes and evaluate

[90] Zerhusen-Blecher, P. et al., 2019. Wirtschaftlichkeit des Anbaus von Erbsen und Bohnen; 5. Hessischer Leguminosentag, Hüttenberg, 10.12.2019; unpublished presentation.
[91] Preissel, S. et al. 2015. Magnitude and farm-economic value of grain legume pre-crop benefits in Europe: a review. Field Crops Res. 175, 64–79.
[92] Jouan, J., Ridier, A., Carof, M., 2019. Economic drivers of legume production: approached via opportunity costs and transaction Costs. Sustainability 11, 705.
[93] Preissel, S. et al. 2015; see above.
[94] Jouan, J., Ridier, A., Carof, M., 2019; see above.
[95] Reckling, M., Hecker, J.-M., Schläfke, N., Bachinger, J., Zander, P., Bergkvist, G., Walker, R., Maire, J., Eory, V., Topp, C.F.A., Rees, R.A., Toncea, I., Pristeri, A., Stoddard, F.L. 2014. Agronomic analysis of cropping strategies for each agroclimatic region. Legume Futures Report 1.4.; www.legumefutures.de.

them with different indicators. Concerning the assessment of financial risks and benefits gross margins of full rotations were considered.[96] This expanded profitability measure averages the sum of all individual crops' gross margins of one rotation in order to receive a comparable annual measure. Suitable crop rotations with crop management were identified by statistical data and experts and included adequate estimates of pre-crop effects. By applying a software that worked based on this data input, a range of rotations were generated. Distinguishing between legume-supported and non-legume rotations comparisons of the assessed rotations could be made. Comparisons were drawn on the level of all generated rotations and on the level of the optimum rotations. Aggregated results on gross margins of all generated rotations showed that legume-based rotations performed better in arable crop rotations in Romania and the UK with advantages between 6 and 22 €/ha per year.[97] In German and Swedish arable systems, legume rotations had on average 20-40 €/ha lower gross margins per year and in Italy the gross margins were with an average of 108 €/ha per year significantly lower. Forage oriented rotations with legumes performed on average better in all compared regions (Germany, Italy, UK, Sweden). The average difference to rotations without legumes was between 4 and 103 €/ha per year.[98] Comparing most profitable rotations with and without legumes at each site supported the findings from the aggregated picture: Adding legumes to the reference arable rotations in Romania and the UK increased the annual gross margins significantly.[99] The most profitable arable rotations without legumes in Germany and Sweden had 19 and 51 €/ha lower gross margins, respectively and in Italy one better performing legume rotation and one with worse gross margin was found depending on the specific region considered.[100]

Enlarging the assessment with environmental criteria can contribute to more comprehensive comparisons of rotations with and without legumes.[101] Following the considerations on possible economic evaluation of positive externalities of legume cultivation (described below), these aspects could in future also practically influence gross margins calculations.

An example from Brandenburg

Following this concept for rotation comparison, the Legumes Translated project implements a similar assessment, however, focusing on selected rotation examples. For this purpose a survey was conducted among all actor groups within the project. The survey focused on exemplary rotations with and without legumes that are relevant in the respective regions. Suitable crop rotations with site-specific crop management were identified within the actor groups and the inclusion of adequate estimates of pre-crop effects was considered. As one regional example, the economic assessment of arable

96 Gross margin calculations included crop yield, price and direct variable costs of production, but did not include labour costs and subsidies. However, Preissel et al. (2015) showed that the inclusion of fixed labour and machinery costs can increase the competitiveness of grain legume rotations.

97 Preissel, S. et al. 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.

98 Preissel, S. et al. 2017; see above.

99 Reckling, M. et al. 2014. Agronomic analysis of cropping strategies for each agroclimatic region. Legume Futures Report 1.4.; www.legumefutures.de.

100 Reckling, M. et al. 2014; see above.

101 Reckling et al. (2014) included environmental indicators as nitrogen balance and efficiency, nitrous oxide emissions and nitrogen leaching.

rotations from the actor group Brandenburg farmers' network in Germany are illustrated in Table 4.[102]

Table 4 Yield[103] and price[104] levels with gross margins at crop-level and average gross margin of arable oriented rotations with and without legumes in Brandenburg, Germany.

	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5	Crop 6	Average GM (€/ha)
Without legume	**WRS**	**WR**	**WR**	**WR**	**WB**		**326**
Yield (t/ha)	3	6.4	5.3	5.3	4.3		
Price(€/t)	360	136	136	136	140		
GM (€/ha)	484	392	293	293	167		
With legume (1)	**WRS**	**WR**	**WR**	**WR**	**L**		**333**
Yield (t/ha)	3.6	6.4	5.3	5.3	2.1		
Price(€/t)	360	136	136	136	206		
GM (€/ha)	639	392	293	293	46		
With legume (2)	**WRS**	**WR**	**WR**	**WR**	**P**		**336**
Yield (t/ha)	3.6	6.4	5.3	5.3	2.5		
Price(€/t)	360	136	136	136	193		
GM (€/ha)	639	392	293	293	61		
With legume (3)	**WRS**	**WR**	**WR**	**WR**	**S**	**SB**	**329**
Yield (t/ha)	3	6.4	5.3	5.3	2.7	3.9	
Price(€/t)	360	136	136	136	368	140	
GM (€/ha)	484	392	293	293	345	168	

Crops: WRS – winter rapeseed, WR – winter rye, WB – winter barley, L – lupin, P – pea, S – soybean, SB – spring barley

Brandenburg is a region with difficult site conditions, with sandy soils and low precipitation that can cause high yield fluctuations which can lead to negative gross margins. Legumes have a minor role and grain legumes that are worth considering were formerly only lupin and pea. Recently the interest in soybean production is rising. The comparison between the non-legume rotation with the three legume-based alternatives shows that all gross margins are on a similar level with a slight disadvantage of the rotation without legumes in comparison to the legume-supported rotations. The best performing legume alternative, the rotation with pea, has a price advantage of 10 €/ha compared to the non-legume rotation. In the exemplary rotations the yield levels of the grain legumes are lower compared to the other crops, however production costs are comparable. Prices for lupin and pea are slightly higher compared to the cereal crops while soybean has a clear price advantage. Following from this, the economic performance of lupin and pea is in comparison to the other crops unattractive, but

[102] Following input from a recent meeting of the actor group additional rotations (i.a. including wheat) will be analyzed and discussed in forthcoming practice guides.

[103] Data are based on a data set which provides cropping systems information on all cash crops grown in the region: Landesamt für Verbraucherschutz LuFB 2016: Datensammlung für die Betriebsplanung und die betriebswirtschaftliche Bewertung landwirtschaftlicher Produktionsverfahren im Land Brandenburg, vol 1. 6 edn., Frankfurt/Oder.

[104] Prices are averages from 2016-2018, retrieved from: https://www.lallf.de/oekologischer-landbau-handelsklassen-mio/mio-marktinformation/. Price levels of legume crops were included based on the "LfL Deckungsbeiträge und Kalkulationsdaten" - https://www.stmelf.bayern.de/idb/default.html;jsessionid=C298F2ABAE74B26C5D8E639D4002122C

soybean have a profitable gross margin. On the rotational scale the less profitable gross margins of lupin and pea can be compensated by their pre-crop effect on winter rapeseed. The yield of winter rapeseed was increased by 0.6 t/ha causing a significant increase in gross margin.

Price variations

Besides the described baseline calculation in which standard prices are assumed for legumes, a scenario with modified legume prices is presented. This feed value price scenario assumes legume selling prices that are equivalent to their actual feed value. With the help of a German feed calculator for pork feed ingredients[105] adapted prices for pea and lupin were provided for the gross margin calculation.[106] Using current wheat and soybean purchase prices[107], the software calculates the equivalent economic value of other products such as lupin and pea on the basis of their most important contribution to pig feeds – which are the essential amino acid lysine and metabolizable energy. Table 5 shows the increase in the lupin price from 206 to 245 €/t and in the pea price from 193 to 256 €/t which results in crop gross margins of 128 €/ha and 218 €/ha respectively. This leads to average gross margins of the whole rotations of 349 €/ha for the lupin rotation and 367 €/ha for the pea rotation.

Table 5 Yield and price levels with gross margins at crop-level for legumes and average gross margins of rotations in scenarios of price and yield variation

	Baseline scenario	Feed value price scenario	Increased yield scenario
Without legumes			
Rotation GM	326	326	326
With legume (1)			
Legume (lupin) yield (t/ha)	2.1	2.1	2.3
Legume price (€/t)	206	245	206
Legume GM (€/ha)	46	128	88
Rotation GM (€/ha)	333	349	341
With legume (2)			
Legume (pea) yield (t/ha)	2.5	2.5	2.8
Legume price (€/t)	193	256	193
Legume GM (€/ha)	61	218	119
Rotation GM (€/ha)	336	367	347
With legume (3)			
Legume (soybean) yield (t/ha)	2.7	2.7	3
Legume price (€/t)	368	368	368
Legume GM (€/ha)	345	345	456
Rotation GM (€/ha)	329	329	348

Yield variations

[105] Landesbetrieb Landwirtschaft Hessen (LLH) (2018) Berechnung der Preiswürdigkeit von Einzelfuttermitteln für Schweine nach der Austauschmethode Löhr. Excel-based calculation tool. Landesbetrieb Landwirtschaft Hessen. Available at: https://www.proteinmarkt.de/aktuelles/schweine/rationsberechnung

[106] Low price levels are a particular issue with legumes other than soybean which is why price variations are only assumed for lupin and pea.

[107] Retrieved from Eurostat – German prices for toasted extracted soyabean meal and fodder wheat from 2018. https://ec.europa.eu/eurostat/data/database.

Following the above described neglect in legume breeding, there is a potential for higher yielding legume species if breeding efforts are increased. In relation to breeding progress in the non-legume species, a yield increase of 10% in the legume yields was assumed in the scenario with increased yields (see Table 5). A lupin yield of 2.3 t/ha would almost double the crop-level gross margin from 46 €/ha in the baseline scenario to 88 €/ha. The increased pea and soybean yields of 2.8 t/ha and 3 t/ha respectively would also result in substantially higher gross margins on the crop level. Considering the average gross margins of the whole rotations, the gross margin gain compared to the baseline scenario rotations range between 8 and 19 €/ha and the soybean rotation would benefit most.

An economic approach for crop rotation assessment

A more economic approach to demonstrate the effects that legumes have in crop rotations was introduced by Carpentier.[108] Carpentier's approach is not particularly defined for legumes and non-legume rotations but applicable for any crop diversification. For practical reasons the formulations were restricted to legume and non-legume rotations. From an economic viewpoint he empirically analyzed and compared legume based crop rotations with reference systems. He also assessed the economic value of legume-supported versus non-legume rotations, but added an analysis in order to uncover the key drivers for this economic value.

The economic value of introducing a legume is defined as the difference in the crop rotations' margins without and with legumes, as considered above in the example from Legumes Translated and Legume Futures. Within Carpentier's illustrative example of the integration of pea in a rotation that is dominated by cereals[109], this economic value is estimated at +12 €/ha. This value is then decomposed in three components: the pre-crop effect value, the cropping system value and the opportunity value or cost. The opportunity cost compares the gross margins of the legume crop and the other crops in the analyzed rotation. Following the considerations from legume's profitability at the crop level in the previous chapter, it is likely that those are negative. This applies also for the opportunity costs of inserting pea in the exemplary rotation which accounts for -33 €/ha. The value of the pre-crop effect takes the impact of the legume crop on the production process of the following crop into account and is therefore only a short run effect. As described in the previous chapter this can enclose decreased input requirements as well as increased yields. For the exemplary rotation this effect is estimated at +33 €/ha and is mainly based on the yield effect that accounts for +24 €/ha. The fertilizer costs of the subsequent crop to pea can indeed be reduced over 30 €/ha, but this effect is diluted along the whole crop sequence to a nitrogen surplus of only 6 €/ha. The third component, the cropping system value measures the economic value of long run effects that lead to annual benefits as effects on pest, weed and soil properties. In Carpentier's example this effect is estimated at 12 €/ha and is due to herbicide savings.

To identify the main drivers for the decomposed value the approach encloses a simple sensitivity analysis. This enables to uncover the crop and/ or input prices that affects the economic value of the legume introduction most significantly. Price and yield of the

[108] Carpentier, A. 2019. On the economics of crop rotation diversification: pre crop, crop rotation and price effects; in: Book of abstracts ECCD 2019, 81-82; https://zenodo.org/record/3516329.
[109] Rapeseed - wheat – wheat – barley vs. rapeseed – wheat – pea – wheat – barley (Carpentier 2019)

legume are very likely to have strong effects and also strongly determined the economic value of the legume introduction in the pea example. Nitrogen price also had a significant impact – the nitrogen cost reductions showed to be more valuable with increasing fertilizer price levels. However, the economic value was only weakly dependent on the pesticide prices according to the sensitivity analysis – but this is likely to be underestimated.

Conclusion on crop rotation effects

The effect of legumes in crop rotations are possibly the most important factor in evaluating their benefits. However, the proper estimation of these benefits are the most difficult tasks. Thorough experiments and empirical work based on the comparison of a wide range of crop rotations in practice would allow a better understanding of these effects.

Challenge of legumes' competitive feed use

The profitable production of legumes in European agriculture is highly depending on its competitive use as feed in livestock production, and, to a much smaller extent, in direct human consumption.[110] Up to now, the largest part of legumes consumed in the EU go to the feeding sector where mainly input prices of feed components and their nutritional value determine the demand. The biggest share of feed protein is mainly imported as soybeans.[111] While legume producers appreciate high market prices, the feed industry and livestock farmers are looking for best value for money for protein and energy components.

Relative value of concentrated feeds

The relative price of a specific feed are decisive for the sale or purchase of feed. It reflects the monetary value that a feed has compared to other alternative feeds based on its specific nutrient or energy content.[112] This "value for money" is based on the content of ingredients that determine the feed value. In many simple calculations, mainly crude protein and energy content are considered. However, feed value-limiting factors also need to be considered (e.g. consumption-depressive or anti-nutritive effects or hygienic-toxicological deviations of the feed) and can be included as additional value factors in the calculations. 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.[113] There is a variety of calculation methods from simple one component methods, two component optimization to linear programming approaches that can consider a multitude of nutrients simultaneously.

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[110] European Commission 2018. Report from the Commission to the Council and the European Parliament on the development of plant proteins in the European Union; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018DC0757

[111] European Commission 2020. EU Feed Protein Balance Sheet 2018-2019 https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/farming/documents/eu-feed-protein-balance-sheet_2018-19_en.pdf

[112] 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.

[113] Steinhöfel, O. (ed.), 2008; see above.

Division method

If only one specific nutrient or energy content is considered, for example if two protein feeds are to be compared with each other, the relative nutrient price can be determined by relating the purchase price to the nutrient unit. The key figure for value for money is then the euro amount of the price or production costs in relation to 10 MJ ME (or NEL) or to one kg of crude protein or lysine.

Price (crude protein) = price per kg of feed / crude protein content

Example:

Soy meal at 0.3 €/kg with a crude protein content of 50 %
Price (crude protein soy) = 0.3 € kg of soy meal / 0.5 kg content of crude protein
Price (crude protein soy) = 0.6 €/kg

If an alternative protein source needs to be compared (e.g. rapeseed expeller at 0.25 €/kg with a protein content of 40 %) the same calculation shows:

Price (crude protein rapeseed) = 0.25 € kg of rapeseed / 0.4 kg content of crude protein
Price (crude protein soy) = 0.625 €/kg

In this example, the soy meal is a cheaper protein source, even though the purchase price is higher.

Optimization methods

When more than one nutrient factor is considered, the division method cannot be used. In practice, the more feed value parameters are taken into account in the relative feed value calculation, the more reliable will be the recommendation. However, the mathematical optimization effort increases considerably with an increasing number of parameters to be considered.[114]

For the evaluation of feed for ruminants, the inclusion of the energy density (MJ NEL or MJ ME per kg dry matter) and the crude protein content is useful. The choice of the parameters can of course be completely different from the respective view of the problem, for example if mineral feeds are to be compared, or in case of pig feeding, energy and lysine content can be considered.

For the calculation of 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. In the majority of cases, feed barley or feed wheat is used as high-energy feed and soybean extraction meal as protein-rich feed. The following is a simple calculation for two feed value parameters (energy and protein). The comparative feed and feed value parameters can be replaced by other nutrient types such as lysine content or other energy parameters.

[114] 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.

1. Calculation of the crude protein factor CP

   Y = ((€ /dt wheat - ((€ /dt soy x MJ ME/kg wheat)/MJ ME/kg soy)

   X = (g RP/kg wheat - (g RP/kg soy x MJ ME/kg wheat)/MJ ME/kg soy)

   Factor CP = Y / X

2. Calculation of the energy factor E

   Z = (g RP/kg soy. x factor CP)

   Factor E= (€ soy. /dt - Z) / MJ ME soy.

   factor E= (€ soy. /dt - (g RP/kg soy. x factor RP)) / MJ ME soy

3. Calculation of the relative price (RP) of an alternative feed

   RP € / dt feed $_{alt}$ = MJ ME/kg feed $_{alt}$ x factor E+ g RP/kg feed $_{alt}$ x factor RP

Based on this calculation approach there are a number of tools available that allow a simple comparison of feed components. For example, Teagasc provides an online version for feed components (see http://interactive.teagasc.ie/Open/FeedStuffs). An offline tool based on an excel spreadsheet is available in German at the Bavarian "Amt für Ernährung, Landwirtschaft und Forsten (AELF) Bayreuth", http://www.aelf-by.bayern.de/landwirtschaft/tierhaltung/198263/index.php. Based on this tool, Legumes Translated provides an updated version on its website in German and English.

Example for other legumes

Applying this tool with current prices of 2020 for a ruminant ration shows the following results (see Table 6).

Table 6 Relative feed values of legumes in dairy feed concentrates

	Values per kg of feed			
Reference feed	Crude protein	MJ NEL		Current prices CW14-2020 €/dt
soy expeller GMO	480	7.1		36.9
wheat, feed quality	120	7.8		16.8
Value factors				
crude protein:	0.058			
energy:	1.257			

	Values per kg of feed		Prices	
feed	crude protein	MJ NEL	Feed value €/dt	Current prices CW14-2020 €/dt
Barley	104	7.5	**15.49**	**14.9**
Maize	95	8.39	16.08	16.6
Rapeseed expeller	406	6.6	**32.00**	**25.1**
Field pea	220	7.5	22.25	18.9*
Faba bean	262	7.5	24.69	19.4*
Blue lupin	385	7.8	32.24	20.2*
Soy expeller Non-GMO	440	7.1	34.56	43.3

* average prices AMI 2019

However, the low and unstable availability restricts a more widespread use of these legumes in feed rations. In the long run, there is a potential for these legumes to fill this gap, if the acreage of rapeseed decreases due to stricter EU insecticide regulations.

Furthermore, if the other benefits of legumes are more known to farmers (e.g. pre-crop value), the availability on European markets is likely to increase.

Legume production and society

Positive externalities

The so far considered effects of legumes produce resource benefits that can be ascribed to individual farming enterprises. However, there are also effects from legume cultivation that can be captured as positive externalities contributing to societal benefits.[115] These environmental benefits include biodiversity enhancement, reduced nitrate leaching, lower emissions of greenhouse gases as carbon dioxide and nitrous oxide emissions or a reduction of international land-use changes if imports from oversea soybeans are reduced.[116] The increased use of legumes as a source of nitrogen in EU farming systems can also reduce the use of synthetic fertilizers which are still mainly produced with a high fossil energy input contributing to greenhouse gas emmisions.

Zander et al. showed the necessity to reward the environmental benefits through more severe mechanisms that extend options within the Common Agricultural Policy.[117] Policies addressing climate change and biodiversity conservation as well as nutrient policies are necessary to value the public goods provided by legumes.[118] Various measures to implement these requirements are under discussion (e.g., a general tax on all fossil carbon sources).

Legumes in the context of a carbon tax

With regard to climate mitigation market-based instruments such as an expansion of the present emission-trading system or a carbon tax are debated.[119] Considering carbon taxes in the context of greenhouse gas emissions from agriculture, the tax could be levied on the use of all fossil carbon sources within the manufacture of synthetic nitrogen fertilizer or on emissions through the use of nitrogen fertilizer.[120] While the latter connects to nutrient policies and needs evaluation of nitrogen surpluses[121], carbon taxes on the production are simpler in implementation. Taking region specific carbon footprint calculations for nitrogen fertilizer production as a basis[122], average emission factors from nitrogen fertilizer production can be used to estimate actual carbon dioxide emissions per unit of fertilizer. Applying for example the western European emission factor of 5.62[123] on the above mentioned amount of fertilizer savings of 30 kg would mean to offset 168.6 kg

[115] Zander, P. et al. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36,1–20.
[116] Bues A. et al. 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.
[117] Zander, P. et al. 2016; see above.
[118] Zander, P. et al. 2016; see above.
[119] Banse, M., Sturm,V. 2019. Preissetzung auf agrarrelevante THG-Emissionen auf der Produktions- vs. Konsumseite: Was bringt mehr?; in: Edmund Rehwinkel-Stiftung der Landwirtschaftlichen Rentenbank (ed.), Herausforderung Klimawandel: Auswirkungen auf die Landwirtschaft und Anpassungsstrategien.
[120] Banse, M., Sturm,V. 2019; see above.
[121] Bues A. et al. 2013; see above.
[122] Manufacturing of fertilizer differ between regions in the world as utilized fuels, energy efficiencies and emissions are varying (Kool et al. 2012).
[123] Kool, A., Marinussen, M., Blonk, H. 2012. LCI data for the calculation tool Feedprint for greenhouse gas emissions of feed production and utilization. GHG Emissions of N, p and K fertilizer production.

CO_2. Depending on the level of the carbon tax, this can then be calculated as cost savings. The price increase of mineral fertilizer through a carbon tax could indirectly support legume cultivation as farmers could react with a stronger interest in fertilizer extensive cropping systems with legumes.

Based on the previous considerations of carbon taxes on the production of nitrogen fertilizer, different carbon tax scenarios were included in the profitability calculations of the rotations provided by the actor group Brandenburg Farmers' network (Table 7). If a carbon tax of 50 € per ton carbon emissions is assumed, the price of fertilizers will also increase, due to the high use of energy for their production. Therefore, the gross margins of the whole crop rotation will decrease between 26 and 29 €/ha. With a carbon tax of 150 € per ton of carbon emissions, a more significant decrease of the average gross margins of all four rotations is given. However, the advantage of the legume rotations over the non-legume rotation increases in both scenarios. Considering the results from the carbon tax scenario of 50 € per ton of carbon emissions, small increases of the advantages are given. In terms of a more drastic carbon tax of 150 € per ton carbon emissions the increases are more significant – the advantage of the rotation with lupin doubles and the advantage of the rotation involving soybean even quadruples.

Table 7 Effects of different carbon tax levels on rotational gross margins caused by higher prices for nitrogen fertilizers

Crop rotation	Average GM (€/ha)	Advantage legume rotation	Average GM with CO_2-tax 150€/CO_2 eq (€/ha)	Advantage legume rotation	Average GM with CO_2-tax 50€/CO_2 eq (€/ha)	Advantage legume rotation
WRS-WR-WR-WR-WB	326		239		297	
WRS-WR-WR-WR-**L**	333	+ 7	253	+ 14	306	+ 9
WRS-WR-WR-WR-**P**	336	+ 10	256	+ 17	309	+ 12
WRS-WR-WR-WR-**S**-SB	329	+ 3	251	+ 12	303	+ 6

Crops: WRS – winter rapeseed, WR – winter rye, WB – winter barley, L – lupin, P – pea, S – soybean, SB – spring barley

Conclusions

Although grain legume production is increasing in Europe, legumes still does not play a significant role. The feed market has a major role in comparison to the food market, but the latter has considerable potential in terms of profitability as legumes targeted for food markets can generally achieve higher prices than feed-targeted grain legumes. European-grown legumes could also exploit consumers' interest and awareness in food of regional origin as well as environmental performance of products through labelling schemes and thereby achieve higher prices.

In conventional arable systems, farmers' cropping decisions are very strongly influenced by the economic competitiveness of each crop within cropping systems. Legume crops are generally regarded as not competitive in comparison with the most profitable cropping options. The information from our actor groups showed no case were legumes are the most profitable crop of a region. However, the profitability of faba bean in Ireland and Germany and the returns of pea in Finland and Germany were shown to be competitive in comparsion with other break crops. Soybean was shown to be even competitive with winter wheat in some situations.

For the most part, farmers in Europe are price takers. The prices they take are determined through the interplay of demand and supply on global or national markets. However, for specific contracts or production that serves premium markets (organic, non-GM, regional markets) there is some room for price negotiations. This is also true for a certain market share of soybeans, which profit from high prices and a high demand for EU-produce.

Overall, production costs play a decisive role for a profitable production of legumes. Keeping costs low, while yields increase through advances in practical knowledge and progress in breeding, can improve the chances of legumes gaining a higher market share.

The positive effect of legumes in crop rotations is possibly the most important factor in evaluating their benefits. However, the proper estimation of these benefits is a difficult task. Thorough experiments and empirical work based on the comparison of a wide range of crop rotations in practice would allow a better understanding of these effects.

From a societal viewpoint, there are effects from legume cultivation that can be captured as positive externalities contributing to societal benefits. These environmental benefits include biodiversity enhancement, reduced nitrate leaching, lower emissions of greenhouse gases as carbon dioxide and nitrous oxide emissions or a reduction of international land-use changes if imports from oversea soybeans are reduced. European consumers will demand for even higher levels of EU legumes based on claims for less imports, no GM produce and arguments around climate change which demand for less synthetic fertilizers and an overall improved sustainability. Policy instruments such as a tax on CO_2 emissions could also improve the competitiveness of grain legumes in European agriculture.

Overall, the competitive value of legumes in agricultural systems cannot be assessed based on only one indicator. The low importance of legumes in the EU could be the result of such reductionistic views, i.e. comparing only gross margins on a single crop basis.

Many factors influence their value in each farming situation. A wider approach that allows to evaluate their effects is needed. By showing the different assessment approaches and applying them to our actor networks data, we hope to have contributed to a more reasonable evaluation.