TRansition paths to sUstainable legume-based systems in Europe

Facilitating the EU market demand for legume-grain and -fodder as feeds

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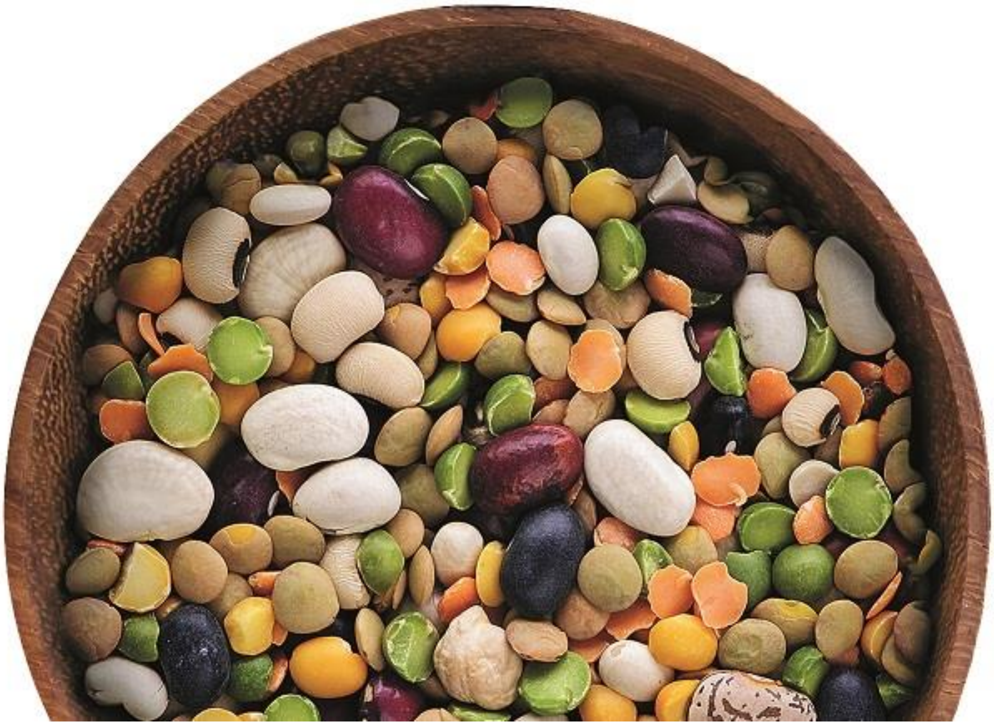

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Deliverable Description & Contributors

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- **Deliverable description:** This report is Deliverable D4.3 (D25) in the TRUE project. The report analyses the present market potential for fodder- and grain-legumes in the EU feed sector including both farm animals and aquaculture. The analysis will touch upon aspects related to value chain organization and markets, drivers and barriers for increasing demand for fodder- and grain-legumes in the feed sector, and with a point of departure being animal nutrition. The report covers a wide range of legume crops including faba beans, soya beans, peas, lupins, alfalfa and clover. A comparative assessment is carried out for European fodder- and grain-legumes in contrast to imported soya beans to assess the competitiveness of European (home-)grown protein crops against international sources. The report's conclusions are followed by a collection of recommended actions to promote a wider cultivation and use of European grown fodder- and grain-legumes in the feed sector.

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- **Key words**

- Fodder-legume; Grain-legume; Soya bean; Pulses; Biorefining; Value chain.

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Glossary

Amino acids: the building blocks that protein is made from. Essential amino acids are amino acids that animals cannot synthesize by themselves so, essential amino acids must be provided in the feed.

Anti-nutritional factors: chemical substances present in the diet which by themselves, or via their breakdown products and at certain doses may reduce the effectiveness of consumed feed.

Bio-based: refers to products wholly or partly derived from biomass from living or once-living organisms. The term can also be used for value chains for bio-based products;

Compound feed: product made from a range of ingredients (e.g. cereals, proteins, vitamins and minerals) by a feed mill. Compound feed is often in the form of pellets and has a relatively high nutritional content per kg.

Conventional farming system: current and most widespread approach in European agricultural production that allows for the use of chemicals and industrial fertilizers in crop production, and where livestock production by far is organised in intensive rearing systems.

COP crop: Cereal, oilseed and protein crops

Cover crop: crop sown after harvest and with the purpose of keeping the land covered with plants to prevent leaching of nitrogen and phosphorous into the aquatic environment. Clover and alfalfa are often used as cover crops.

Crude protein: the protein content of a feed, for example faba beans have ca. 25-30 % crude protein and soya bean meal 44-48 %, assessed as 6.25 × N.

Digestible protein: only part of the protein in feed can be digested by the animal, this is the digestible protein.

Farming system: the way the farm production is organised. A farming system may be intensive (i.e. based on intensive animal and crop production, high-input high-yield approach), for example modern indoor pig production. Extensive farming uses a lower-input approach by for example using native livestock breeds, grazing on marginal lands.

FEFAC: European Feed Manufacturers Association, www.fefac.org

Fodder: Animal feed comprising green vegetative material during the vegetative and/or late-reproductive life history stages. Used for domesticated livestock, fodder is typically of high fibre content, in addition to protein and carbohydrate provisions. The green material may be cut (and processed into pellets or bales), to feed contained livestock or, may be foraged by livestock directly in the fields.

GMO: genetic modified organism.

Grain legume: dried grains from faba beans, peas, lupins, soya beans

Non-GMO: a term used for crops that are not made from genetic modified plants.

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Ha: for Hectare or 10.000 m^2, a unit used to describe a measure of land area.

Home-grown: “locally” in the meaning of European produced crop in contrast to imported crop.

Leguminous plants: family of plants with nitrogen fixing capabilities, including species with relevance as feed crops such as alfalfa, clover, vetches, peas, and faba beans. In this report also lupins and soya beans are regarded as ‘leguminous plants’ or ‘grain legumes’ even if (like pulses) are also categorised as ‘oil crops’ (i.e. yield oleaginous grains), and their green vegetative material used as fodder.

Mono-gastric: group of animals with only a single stomach, i.e. pigs, poultry, horses and fish.

Organic farming system: current approach in European agriculture that does not allow for the use of chemicals or industrial fertilizers in crop production, livestock production is less intensive than for the conventional system, and the use of industrially produced enzymes, amino acids and antibiotics is not allowed.

Pedo-climatic area: climatic zones characterised by its rainfall, temperature and moisture.

Protein ingredient: the source that is used to provide the protein in the feed, for example faba beans, soya bean meal or skimmed milk powder.

Pulses: non-oleaginous dried grains from crops such as peas, faba beans, chickpea, lentils and common bean. Their characterisation as ‘pulses’ is mainly on the basis that their main carbohydrate reserve is starch. Here in this report the dominant feed crops are discussed, specifically peas and faba beans in a feed context.

Roughage: feed with a fibrous structure and relatively low to medium nutritional content per kg. Examples of roughage are hay, dried alfalfa and silage made from clover-grass.

Ruminants: group of animals with four stomachs, i.e. cattle, sheep, goats.

Soya bean equivalent: unit used to convent protein content of diverse feed sources into soya bean meal 44 % protein content. The latter is used as an international point of reference for protein content in feed.

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Executive Summary

The scope of this Deliverable, in the following referred to as the *report*, is to provide a qualitative assessment of the competitiveness of European-grown fodder- and grain-legumes for the feed sector in contrast to imported soya bean feed. The assessment of competitiveness will build on a value chain approach and include qualitative and quantitative data. The report is centred around protein feed, as the current challenge is to expand European-produced protein feed and, for this, fodder- and grain-legumes are significant. The report builds on desk research, case studies with practitioners, research experiments, and stakeholder consultations.

Faba beans are used for animal feed as well as other grain legumes including soya beans and soya bean meals. The key issue of feeding livestock and farmed fish is the optimal provision of nutrients. This frames the main challenges and opportunities dealt with in this report. Livestock producers demand the best nutrition at the best price, so the animals stay healthy and perform well. Animal diets are formulated according to availability of feed sources and nutritional requirements. Special requirements prevail for diets targeted at organic and non-GMO farming systems, encouraging local value chains for fodder- and grain-legumes.

EU Feed mills source feed ingredients locally or from international suppliers. Feed ingredients are traded as, for example, soya beans and soya bean meals, and trade is based on world market prices and transparency. European grown fodder- and grain-legumes are mainly traded locally, however there are interesting prospects in terms of the cultivation of green fodder legumes in the EU for exports to the Middle East, China and Japan. There is therefore huge potential for worldwide expansion of the range and scale of European legume cultivation and market competitiveness.

The potential for transition towards a greater proportion of fodder- and grain-legumes in European agricultural production is already evident and we are now presented with a huge opportunity to establish an EU agri-food system where production of feed protein (and other feed sources) is

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organised in a manner that favours positive impacts on the 'triple-bottom line' [1] of economy, environment and society. Therefore, the transition must take place at a pace that allows the value chain actors to engage and to adapt the production system and trade patterns accordingly. This should be rooted in the local context but not necessarily limited to a local value chain. Crop rotations are planned several years ahead, and for example this means that only every fifth to seventh year will accommodate a legume crop in the rotation. Regulations at EU and Member State levels regarding the safeguarding of the aquatic environment and water resources have targeted agricultural production and land use for many years and will continue to show an impact on land use in the near future.

Farmers will only grow crops that are economically viable and fit for purpose (e.g. on-farm use, for sale or as part of a land management effort), so incentives for growing a particular crop type must be considered in relation to the wider perspective including value chains and markets, environment, and social aspects. Innovative approaches to processing fodder- and grain-legumes for feed purposes could form an integrated element in modern rural development as this would allow for new business models for farmers and promote the development of new (bio-based) value chains. Also, local facilities for drying and processing fodder legumes contribute to the triple-bottom line and could encourage legume cultivation on a larger area.

Fodder- and grain-legumes for feed is a comprehensive topic and, it includes much more than "pulses for compound feed". New approaches are regarded as fundamental for increasing supply and demand of fodder- and grain-legumes for feeding animals. Therefore, the report shows a range of examples of new ways to incorporate fodder- and grain-legumes into value chains for feed. The opportunities for using grain legumes in new diets for e.g. farmed fish or shrimps or, from expanding a current market-competitive position within dried green fodder should be high on the agenda by value chain actors, investors, and policy makers.

The most effective way to effect change is through co-ordinated effort in addressing opinions regarding the acceptability of established practice. For example, there is common opinion that

[1] The triple-bottom line frames the economic, environmental and social impact.

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"soya bean meal is the only really good, inexpensive protein source". This has come clear from stakeholder consultations at the LIN meetings, interviews, and the Danish case study about organic feed. In addition, the large share of the protein supply that is made up of soya beans and soya bean meal shows the importance of this specific type of protein feed (see e.g. Friends of the Earth Europe, 2018)". Here, education of farmers and knowledge providers, plus demonstration of new practices related to growing and processing legumes of a wide range of species are an essential step in the transformation to encourage more widespread legume production. It is a well-known fact that if you 'see something that works' then one is more willing to try this new approach. Different farming systems (e.g. organic farming, non-GMO farming systems, conservation agriculture etc.) have their focus on the requirements to source feed and to implement effective feeding strategies. It takes nutrient-dense feed to care for high-yielding animals, so a change to another feed source may seem easy but could have a significant impact on animal productivity, farm income and management.

The topic of legumes, pulses, protein feed plus value chain opportunities and barriers is highly complex and under-researched. The topic therefore holds an untapped potential for provision of animal nutrition, income generating activities and measures for mitigating climate change. Finding solutions is challenging across many diverse stakeholder groups yet, the way forward builds on common understanding and a will to collaborate with the goal of increasing local supply and demand of European fodder- and grain-legumes for feed purposes.

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1 Introduction

1.1 Scope of the Deliverable

The scope of the Deliverable, in the following referred to the *report*, is to provide an assessment of the competitiveness of European-grown fodder- and grain-legumes for the feed sector in contrast to imported soya bean feed. The assessment of competitiveness will build on a value chain approach and include qualitative and quantitative data. The report is centred round protein feed as the current challenge is to provide an expanded European produced protein feed and for this, fodder- and grain-legumes come into play.

To enhance understanding of the complexity of the feed value chain a section about feeding animals has been included. This section introduces principles of feeding livestock and farmed fish and by that frames the demand side of the value chain. Having more European-grown fodder- and grain-legumes in the value chains for feed is strongly linked to motivating factors and bottlenecks for producing, processing and trading feedstuffs, hence challenges and opportunities of the supply side. The analysis covers conventional and organic feed value chains.

New approaches are regarded as fundamental for increasing supply and demand of fodder- and grain-legumes for feeding animals. Therefore, the report shows a range of examples of new ways to incorporate fodder- and grain-legumes into the value chains for feed.

The report presents a comparative assessment of European fodder- and grain-legumes compared and contrasted to imported soya bean feed by addressing animal nutrition, provision of protein feed, and factors with relevance for facilitating trade. Conclusions are drawn out about challenges and opportunities for having more fodder- and grain-legumes in the European value chains for feed including a list of recommended actions to facilitate this transition.

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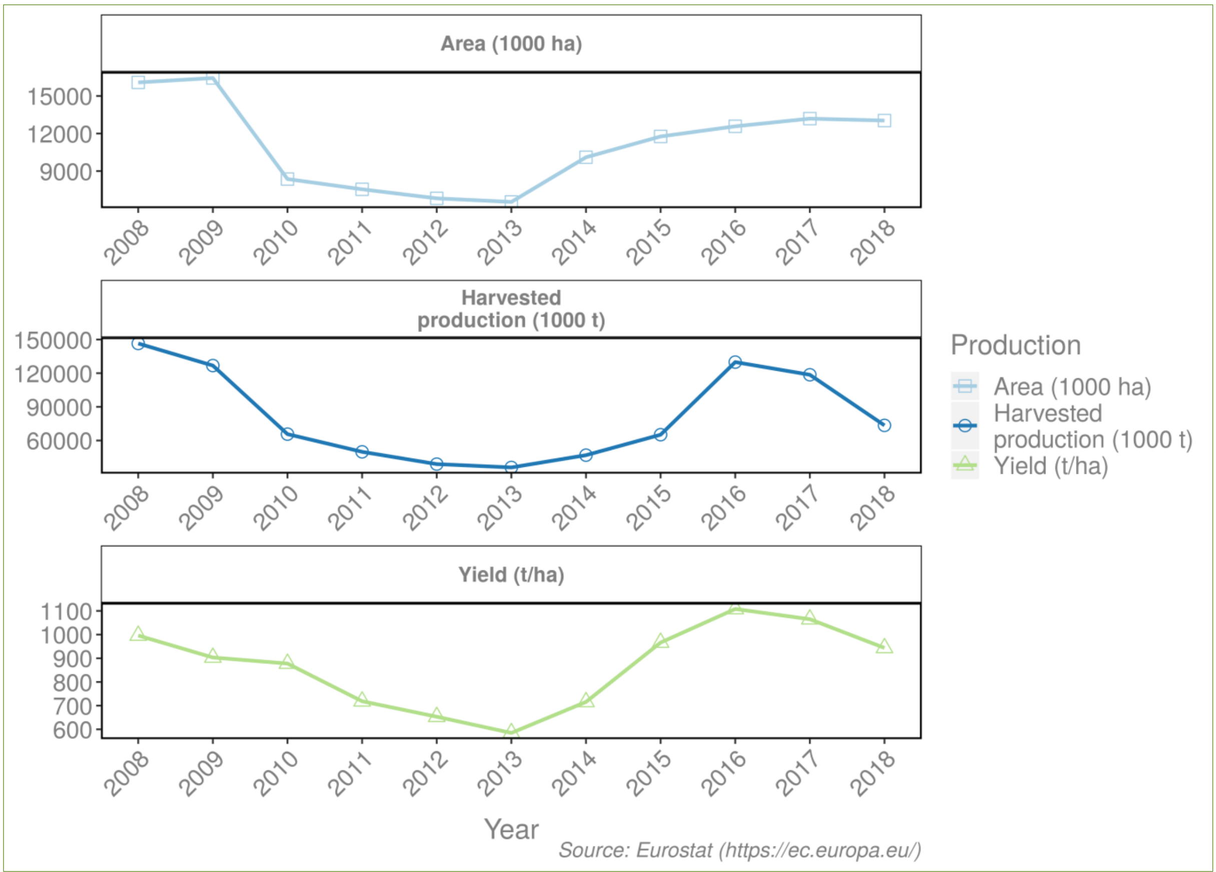
2 Production of fodder- and grain-legumes in the EU

2.1 Production of grain legumes in the EU

From 2008-2013 the EU saw declines in area under cultivation, harvested production, and indicator 'yield'. From 2013, after the substantial review of the Common Agricultural Policy, each of these metrics gradually increased, albeit with some variation and fluctuation, as indicated in Figure 1.

Figure 1: Total area, production and yield of grain legumes in EU (2008-2018).



(Eurostat data)

The development pattern shown in Figure 1 demonstrates that EU agricultural policies have a significant impact on farmers' choice of crops. Data from Germany shows that production of faba beans increased from 60,000 tons in 2013 to 190,000 tons in 2017. This more than tripling of the production was mainly caused by CAP greening measures. Many EU states offered supplemental subsidies within specific programs, such as more diverse crop rotations, to motivate cultivation of

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legumes (Sepngang et al., 2018). Clearly, agricultural policies can be shaped to address issues related to other policy areas such as environmental impact on soil, water and biodiversity and, encouragement of selected value chains and business patterns. Some of these aspects will be addressed in this report.

Data from the decade 2008-2018 show that harvested production of fodder- and grain-legumes in the EU fluctuate wildly (Eurostat, as presented in Figure 2). From Figure 2 the harvested production of grain legumes has evolved quite slowly since 2008. The main factors behind this development pattern are perceived to be: farmers' income; in-coherent value chains; changes in support measures; and, seed material that is not well suited to the agricultural conditions. The latter reason was brought forward at LIN meetings in the UK, in Germany, and from a survey among Danish organic farmers (refer to Lambertsen, 2019) and from analysis of the potential for using clover-grass for bio-refining (Hamann and Gylling, 2020). An example of the latter is the challenges that farmers in the Nordic countries experience from large variations in the yield of faba beans. It is claimed that better seed material would motivate more farmers in Nordic countries to grow faba beans because farmers are risk-averse and will choose a crop with a less variable yield (Lambertsen, 2019).

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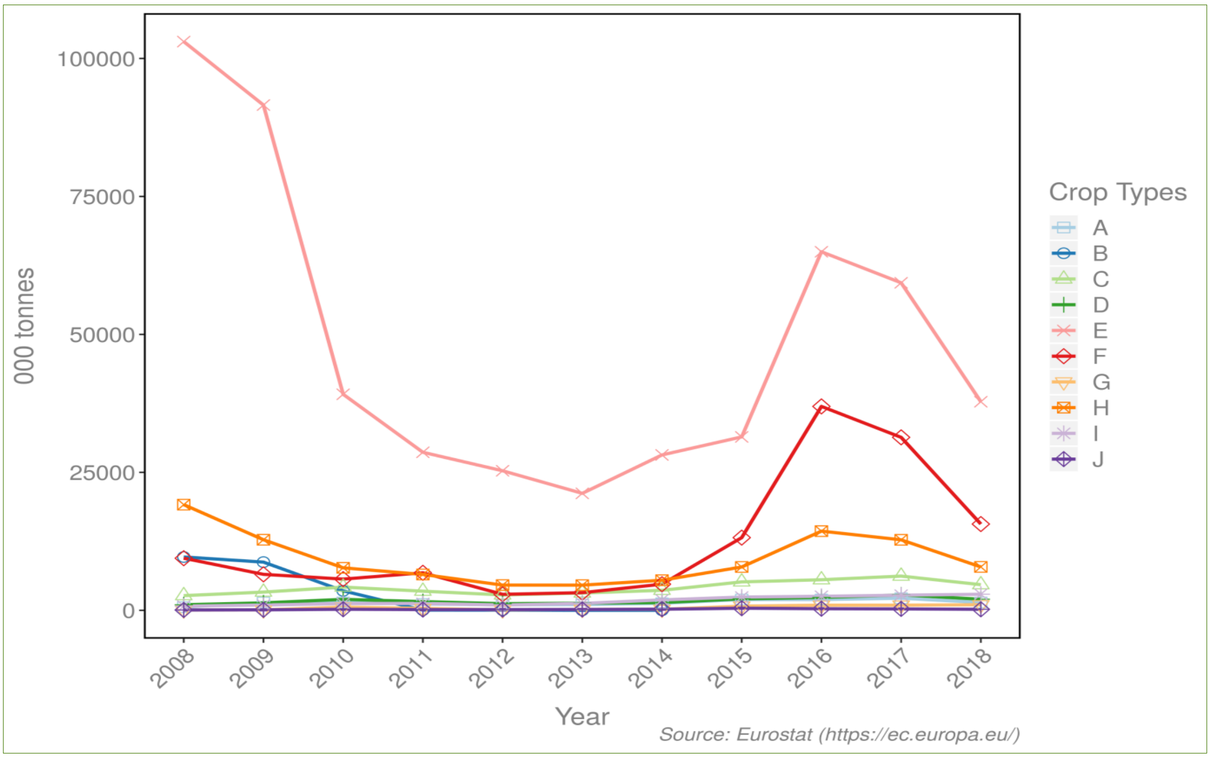
Figure 2: Development in production of fodder- and grain-legumes by type of crop, in 1000 tons.



(Eurostat data); Legend: **A**, Broad and field beans; **B**, Clover and mixtures; **C**, Dry pulses and protein crops for the production of grain (including seed and mixtures of cereals and pulses); **D**, Field peas; **E**, Leguminous plants harvested green; **F**, Lucerne; **G**, Other dry pulses and protein crops not elsewhere classified; **H**, Other leguminous plants harvested green not elsewhere classified; **I**, Soya beans; **J**, Sweet lupins.

Table 1 shows the development in area, production and yield for fodder- and grain-legumes for the last decade. The soya bean area in the EU has doubled to one million ha since 2013, with an EU production of 2.8 million tons in 2018. The main soya bean producers are Italy, France and Romania. Since 2013 the pulse area in the EU has almost tripled and reached 2.6 million ha in 2018. Grain legumes and fodder legumes (clover, alfalfa) supply around 3 % of the EU protein need for animal feed. Poultry production in Poland, Hungary and Romania is increasing and these large countries are important for European grown plant proteins, particularly soya beans. Major agri-business companies such as Cargill and ADM are investing in soya bean production in East Europe (Friends of the Earth Europe, 2018). This would lead to an increased production of soya beans in EU.

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The EU grain legume crop (mainly field peas and faba beans) amounted to 6 million tons in 2018, yet grain legume crops are harvested as pure crops (e.g. only peas) or mixed crops (e.g. peas and barley). Furthermore, a share of the crops is produced as seeds. Therefore, it is difficult to assess the exact harvested volume that can be used for feed, food and other purposes (Table 1). Grain legumes and legume fodders account for less than 6 % of EU arable land.

Table 1: EU production of fodder- and grain-legumes by type of crop and year, in 1000 tons.

Year	Broad and field beans	Clover and mixtures	Dry pulses and protein crops[a]	Field peas	Leg. plants harvested green	Lucerne	Other dry pulses and protein crops[b]	Other leg. plants harvested green[b]	Soya beans	Sweet lupin
2008	576	9668.36	2666	1015	103055	9442	59	19151	765	61
2009	1413	8737	3305	1352	91556	6519	76	12789	964	87
2010	1428	3530	4212	1990	39148	5661	598	7701	1234	192
2011	1150	41	3469	1584	28637	6798	357	6496	1253	134
2012	1004	37	2788	1209	25285	2904	78	4575	970	130
2013	1045	6	3136	1294	21195	3206	168	4564	1256	152
2014	1271	9	3628	1402	28158	4740	184	5456	1892	208
2015	1953	NA	5153	2079	31424	13173.94	768	7854	2406	379
2016	1955	NA	5541	2333	64974	36950	932	14351	2546	295
2017	2191	NA	6203	2783	59349	31345	938	12775	2744	262
2018	1422	NA	4649	2016	37795	15632	1012	7864	2913	185

(Eurostat data); [a] including legumes for production of grains, seeds and mixed crops with pulses; and [b] is not classified elsewhere

The extent of cultivation of grain legumes is related to pedo-climatic zone. The main producers of soya beans are located in Central and East Europe, whereas pea production takes place mainly in the Atlantic and Baltic areas, especially in France, Spain and Lithuania (Figure 3). The largest producers of lupins are currently Poland and Germany. Faba beans are grown across the EU, but mainly in the Atlantic and Western areas (especially France and the UK). Major producers of fodder legumes are Italy, France, Spain, Romania and Poland.

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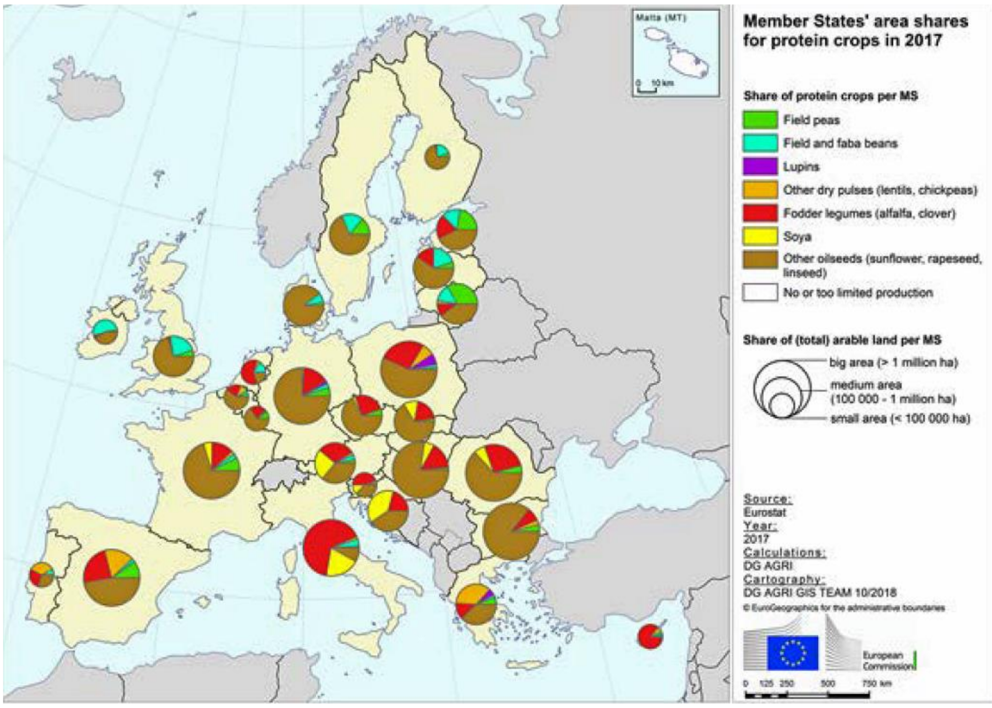
Figure 3: Member States' area shares for protein crops in 2017.



(Mögele, 2018; based on data from Eurostat and DG Agri)

The pulses-cultivated area was stated at 1 million ha in 2012 and is forecasted to grow to 2.3-2.4 million ha by 2030 (European Commission, 2019a). Pulse crops are sensitive to weather conditions making a prediction of yields difficult. Yet, the production of pulses in the EU is anticipated to reach a volume of 6.3 million tons in 2030 (European Commission 2019a). Further, it is expected that the inclusion of pulse crops into feed rations will increase because of demands for more diversified protein sources and a better availability of European pulses to farmers and feed mills (European Commission, 2019a). Motivating farmers to include more pulses in crop rotations will play a significant role for achieving this development path.

The EU area to be cultivated with soya beans is foreseen to increase from 0.4 million ha in 2012 to 1.3 million ha in 2030, up from 1 million ha in 2019. The growth in soya bean production is foreseen to be modest despite improved farming practices. By 2030, it is assumed that EU soya bean production could reach 4.1 million tons equal to 20 % of the EU consumption of soya beans. Oilseed crushing accounts for 90 % of soya been consumption in the EU. As the EU pig production will increase, imports of soya beans will increase further in the near future. It is forecasted that imports of soya beans will grow to 17.2 million tons in 2030, up 2.1 million tons compared to the current situation (European Commission, 2019a).

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2.2 Grain legumes and trade

The EU imports ca. 13-14 million tons of soya beans per year. These soya beans are sold to the EU oilseed crushing industry and the co-products (meals and cakes) are used in the feed industry. A minor share of imported soya beans (7 %) is for food (Agrosynergie, 2018). Following an agreement between the USA and EU from July 2018, the two parties have agreed to increase trade in soya beans (Figure 4). This makes the USA the largest exporter of soya beans to the EU providing 74.5 % of EU soya bean imports. Comparison of imports from July-December 2017 with the same period in 2018 shows that imports of soya beans from the USA to EU increased by 112 % to 5.2 million tons (6 months of import). This increase places USA well ahead of the second largest exporter to the EU, Brazil, with a market share of 19 % (Figure 5). Other suppliers of soya beans to the EU are Canada (2 %), Ukraine (1.6 %) and Paraguay (1 %), (European Commission, 2019b).

Figure 4: Exports from USA to EU of soya beans.

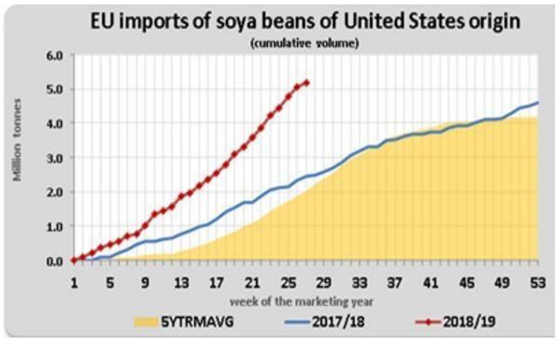
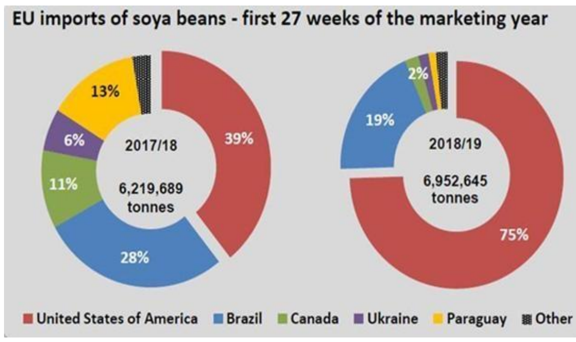


Figure 5: EU imports of soya beans, by country 2017 and 2018.



(Figures retrieved from https://ec.europa.eu/commission/presscorner/detail/en/IP_19_161)

Currently, EU imports about 20 million tons of soya bean meals for feed purposes. This is forecasted to grow to 22 million tons by 2030 (European Commission, 2019a).

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Dried legumes such as alfalfa and vetches are exported from EU to Third Countries[2] in particular United Arab Emirates and China in the form of pellets or bales. Spain is the largest producer and exporter of dried fodder in the EU and, the third largest in the world following United States and Australia. In Spain, alfalfa is considered as a nitrogen-fixing crop for greening compliance purposes and farms of more than 15 ha must devote over 5 % of the cultivation land for greening compliance. Following this measure, a part of the alfalfa crop is cultivated without the use of plant protection products. It is claimed that the current EU support measures are insufficient to influence farmers' planting decisions as farmers will plant the crop that ultimately is expected to provide the best margins (Clever and Guerrero, 2018). This dilemma is important to address in a policy context if the intention is to increase the European cultivation of fodder- and grain-legumes, as cultivation and processing of for example alfalfa (Figure 6) holds a large potential for export earnings, employment and the subsequent environmental benefits that follow from cultivation of legumes.

Figure 6: Exports from Spain stimulate cultivation of alfalfa for dried fodder.

The most important fodder crops in Spain are alfalfa and vetches. Alfalfa is planted on irrigated land in the Ebro Valley and on non-irrigated land in Castilla y Léon; these are the two most important regions for producing alfalfa in the country. The crop from Ebro Valley is export oriented and shipped to the market from the port of Barcelona. The domestic market is supplied by the crop from Castilla y Léon. In total 2018, ca. 1.5 million tons of dried fodder was produced under contract with dehydration plants. This volume is in line with the production of 1.4 million tons in 2014.

There are 34 processing plants for manufacturing dried fodder, hereof 45 in the Ebro Valley. The Spanish export of dried fodder has increased from 982,000 tons in 2014 to 1,111,700 tons in 2018. 53 of the Spanish plants are approved of for export of dried fodder to China and 58 for exports to Iran. By 2018, 75 % of the Spanish exports of dried fodder were destined for the Middle East and 8 % to China. The United Arab Emirates is the single largest market and imported 552,000 tons of dried fodder from Spain in 2018.

(Based on insight described in Clever and Guerrero, 2018)

[2] Third Country refers to a phrase used by the EC to characterise a country which is not a member of the EU Union. This is of particular utility when referring to relations between two EU Member States and another country, or literally 'Third Country' which is outside the European Union.

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2.3 Organic production

Grain legumes are frequently cultivated organically in EU agriculture. Since 2012, the organic grain legume crop has increased from ca. 1.7 million tons in 2012 to 2.5 million tons in 2018.the organic soya bean crop has shown a smaller increase from 1.4 million tons in 2012 to1.6 million tons in 2018. It is not possible to see from the data how these crops are shared between food and feed, but the clear trend is an increasing production of organic legumes and soya beans. EU is not self-sufficient in organic soya for feed. Currently the main supplier of organic soya to the EU is China. As the organic livestock production is increasing in the EU there is a need to increase the supply of organic feed, especially protein. This is further elaborated in section 5 with examples of new ways to use fodder- and grain-legumes for feed.

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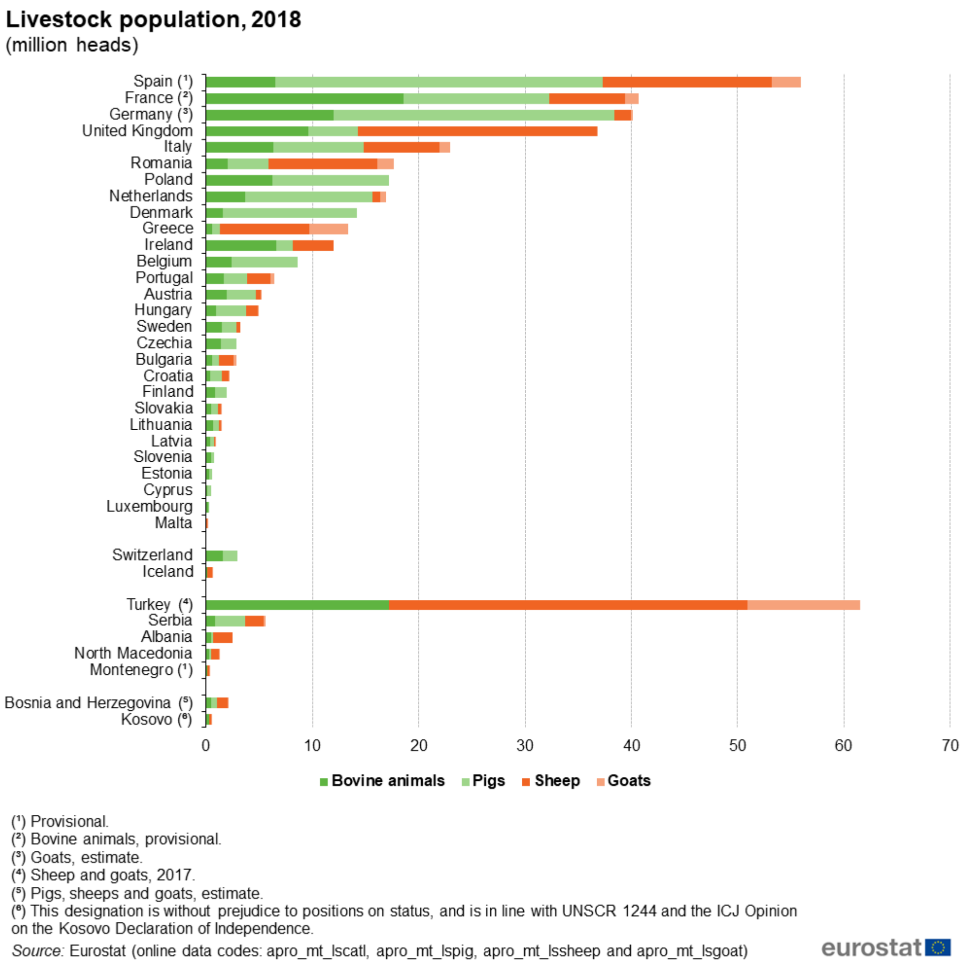
3 Demand for protein feed

3.1 Livestock production

The livestock population in the EU encompasses pigs, cattle, sheep, goats and poultry to produce meat, milk, wool and hides. Most of the livestock are kept in just a few Member States (Figure 7). Three quarters of the bovine animals were kept in France, Germany and the UK. Spain, Germany and France are the largest producers of pigs, holding nearly three quarters of the EU stock. Two thirds of the sheep are found in the United Kingdom, Spain and Romania, and two thirds of the goats are kept in Greece, Spain and Romania (Eurostat, 2019).

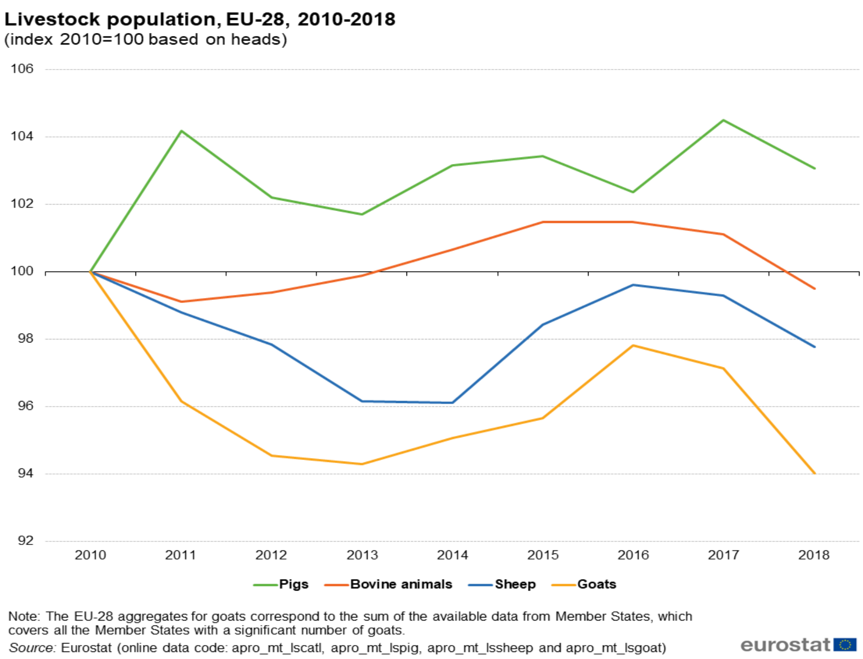
Figure 7: Livestock population by EU Member State, 2018.



(Eurostat, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Livestock_population,_2018_(million_heads).png)

By 2018, there were 148 million pigs, 87 million bovine animals, and 98 million sheep and goats in the EU. Phasing out of the milk quotas led to a decrease in the number of bovine animals and small ruminants (Figure 8). The pig production cycle is shorter than that of the bovine animals because of shorter gestation and fattening periods, hence pig production can faster adapt to changes in production conditions. To feed the farm animals, the EU feed industry provided 159 million tons of compound feed (refer to section 4.1). In addition, feed produced and used by the farms contributed with ca. 30-40 % of cereals and grains legumes such as peas (European Commission, 2017a), and feed provided from grazing and production of dried fodder. The EU livestock production demands a huge volumes and diversity of feed and this is a challenge as well as an opportunity for expanding the use of fodder and grains legumes. This will be explained further in the following chapters.

Figure 8: Development in EU stocks of pigs, cattle, sheep and goats 2010-2019 (stocks of 2010 = index 100).



(Eurostat https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Livestock_population,_EU-28,_2010-2018_(index_2010%3D100_based_on_heads).png, accessed March 2020)

3.2 Aquacultural production in the EU

Production from aquaculture has remained quite stable during the last decade amounting to a volume of 1.3 million tons; this corresponds to one fifth of the EU fisheries. For comparison, the Norwegian aquaculture production stood at 1.3 million tons in 2018. The EU aquaculture production includes molluscs, crustaceans and farmed fish. Spain, United Kingdom and France are the top-three producers of aquaculture in the EU. Salmon and trout account for one third of EU aquaculture production (Eurostat, 2019b). Due to the scale of the EU aquaculture production and given the fact that a significant share of the diets for farmed fish can be replaced by grains legumes (refer to section 5.1 and 5.2) there is a significant potential for increasing the use of grains legumes in feed for farmed fish.

3.2.1 Feeding livestock

Livestock diets must provide the animal with adequate supply of nutrients, mainly in the form of macronutrients like proteins, energy and fibres. Hereto must be added micronutrients like vitamins, minerals, essential amino-acids, essential fatty acids and more. Diets are formulated to match the requirement of the animal by addressing several parameters, including the following.

Species: ruminants and horses thrive on high-fibre diets, whereas mono-gastric animals (pigs and poultry) need diets that are much lower in their levels of fibre. Diets for aquaculture seek to replace fish meal with alternative protein sources and fish oil with alternative sources of omega-3 fatty acids.

Breeds: breeds used in intensive farming systems need diets with a high digestibility of the nutrients. Breeds for extensive farming systems require diets with lower nutrient densities than breed used for intensively farmed systems. The adaptation of diets to the particularities of the breed is relevant for all species used in farming systems and aquaculture.

Production system: the range of production systems considered in this report includes the conventional farming system, organic farming systems, and non-GMO systems (refer to section 3.2.2). The production system determines the inputs and production methods that are applied (for example the requirement of organic agriculture not to use chemical fertilizers and pesticides).

Age / phase of life: feeding animals must be adapted to the age and activity of the individual. This is due to the need for and digestibility of nutrients. Piglets, for example, must be fed a diet that is high in highly digestible protein and very low in fibre, whereas a sow can thrive on a diet where fibre accounts for up to 50 % of the nutrient supply. Furthermore, diets must be adapted to the stage in the reproduction cycle (gestation, lactation, or dry period), or the production cycle as for example piglets vs. finisher pigs. The same principles apply to feeding fish.

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Protein demand and essential amino acids: the general principle is that the more demanding performance required from the animal, the higher demands there are to the digestibility and nutrient density of the diet. In most cases protein and especially protein quality is considered as the limiting factor. As protein consists of amino acids, and the animal requires a sufficient amount and combination of essential amino acids, diet formulation for monogastrics is designed to ensure that essential amino acids are supplied; ruminants can to a large extent rely on essential and non-essential amino acids supply from microbial protein production in their rumen, derived from any source of degradable nitrogen (Kumprecht, 2018). The most considered essential amino acids are lysine, methionine and threonine. In practise, the sufficient provision of essential amino acids is overcome by formulating diets to include this as a minimum volume and this approach very often leads to over-supply of most of the other amino acids – in reality an over-supply of protein.

It is therefore necessary to consider what types of fodder- and grain-legumes that are available from European sources and how this could be used to feed the livestock and farmed fish produced in the EU (Table 2). Green fodder legumes (alfalfa and clover) are used as silage, for grazing or as dried feed. Grain legumes such as peas, faba beans and lupins are used as ingredients in compound feed for various animals. Pigs and poultry would feed on clover in free-range production systems where the animals have access to outdoor areas. Farmed fish such as trout and salmon need protein with a very high digestibility, and this could be meals from grain legumes. Soya bean meals are used for all farmed species.

Table 2: Suitability of fodder- and grain-legumes as feed for diverse animals.

Suitability of legumes, pulses and soya feed	Bovine and small ruminants	Pigs	Poultry	Horses	Farmed fish
Alfalfa	X			X	
Clover	X	X	X	X	
Peas		X	X		
Faba beans	X	X		X	X
Lupins	X				X
Soya bean meals and cakes	X	X	X	X	X

Own elaboration, 2020. Legend: X indicates that the feed is suitable for the species.

Table 2 shows that fodder- and grain-legumes can be used as feed for diverse groups of animals. The use of fodder- and grain-legumes can be increased in volume and diversity by considering how to process fodder- and grain-legumes, and the composition of the diet. This will be further explained in the report. Another option for increasing the use of fodder- and grain-legumes is to look at the

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integration of livestock production with agroecological practices, but that is beyond this report's scope.

3.2.2 Farming systems and requirements to feeding livestock

Livestock production can be part of many diverse farming systems; conventional, organic and non-GMO, integrated, agroecological etc. For each system there are requirements for the type of farm inputs that may be used as well as demands with respect to the management and facilities at the farm. In conventional agriculture, the main sources used for feeding livestock are cereals, meals and cakes from oilseeds, silage and dried fodder (Major 2018 and section 4.1). As soya bean meals is a highly nutritious feedstuff and available at a competitive price, it is widely used as the main source of protein feed for pigs, poultry, cattle (dairy and beef production), horses and sheep. Further for conventional farming, farm inputs such as antibiotics, industrially produced amino-acids, feedstuffs derived from (GMO) plant materials, NPK-fertilizers, and pesticides may be used.

In non-GMO farming systems, only feedstuffs made from GMO-free plants can used to feed livestock. By 2015, 8.3 % of the soya beans imported to the EU and 11.3 % of the soya bean meals were certified as non-GMO. The imported non-GMO volume amounted to 2.7 million tons of soya bean equivalents (Tillie and Rodriguez-Cerezo, 2015). Non-GMO farming is recognised as a premium farming system as is organic farming, and both systems target premium inputs, high standards in farm production, and a high-priced consumer market. In 2011, non-GMO farming systems accounted for 11 % of the feed used in the EU. Austria is among the top users of premium farming systems, as 100 % of the milk is produced by cows fed GMO-free diets, and 15 % of the milk came from organic farms, Table 3. The importance of soya bean meal as protein source is highly evident for pigs, as only 8 % of the Austrian pigs were fed a GMO-free diet, and 2 % of the pigs were farmed organically (Mögele, 2018).

Table 3: Organic and GMO-free farming systems in per cent of all farms in Austria, 2018.

Segment	**Organic farming**	**GMO-free farming**
Cattle (for beef)	21 % of cattle	no data
Dairy cows	15 % of the milk	100 % of the milk
Layer hens	12 % of the hens	80-90 % of the eggs
Broilers (chicken)	10 % of the broiler production	100 % of the chicken
Pigs	2 % of pigs	8 % pigs

(Based on Mögele, 2018)

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A scenario analysis has been carried out (European Commission, 2019a) for dairy production, and this considered: *what would be the impact if all milk produced in the EU would be from non-GMO farms within the next four years?* The analysis showed that by turning 100 % non-GMO, the composition of dairy feed turns into 13 % less soya meal, 9 % more rapeseed and sunflower meals, and 5 % less cereals. The EU soya bean area increases by 51 % (= 0.6 million ha) and the pasture and fodder area by 2.8 million ha. The change in production systems towards more pasture and fodder pushes the cereal and oilseed area down. As a reaction to increasing demand, the EU price on soya beans experiences a substantial increase of 53 % whereas the rapeseed and wheat prices increase moderately by 8 % and 3 %, respectively (European Commission 2019a). This scenario demonstrates that non-GMO could pave the way for new European crops and value chains for protein feed due to higher prices. This would also benefit new protein value chains within organic agriculture.

It is a requirement in organic farming that the feed is produced on-farm or within the region – yet "region" is not clearly defined. Following the requirements for using 100 % organic protein feed and the feed being of home-grown origin, demand for organic protein is foreseen to increase. This highlights the need to identify alternative protein sources to organic soya beans and, this is where the European grain and fodder legumes come into play.

Organic agriculture is subject to specific rules for farming and food chain system as defined in the EU Regulation n°. 834/2007 on Production and Marketing of Organic Products. All farmers in the EU who produce under the organic farming system are subject to follow the same rules and their products can be labelled with the EU organic logo. The organic farming and value chain system requires that the farm inputs are of organic standards, for example feed and seeds. According to the EU Regulation no 834/2007, all feed used by organic farms must be 100 % organic as of January 1st, 2021. This rule is supplemented by a new rule for an intermediate period allowing the feed used for young animals to only be 95 % organic. In a protein context this is important as young animals need relative high protein content in their diets. Livestock produced under organic farming conditions may not be fed synthetically produced amino-acids and this is important for the pig and poultry sectors. If animals are under-supplied with essential amino-acids such as lysine for pigs and lysine and methionine for poultry (layer-hens), this has a negative effect on growth and production (Steenfeldt and Poulsen, 2018).

The share of organic livestock in total EU livestock is increasing (Figure 9). The demand for organic compound feed is most significant for pigs and poultry and less for cattle and small ruminants. This is because grazing and pasture-based production systems are important in organic cattle, sheep and goat farming.

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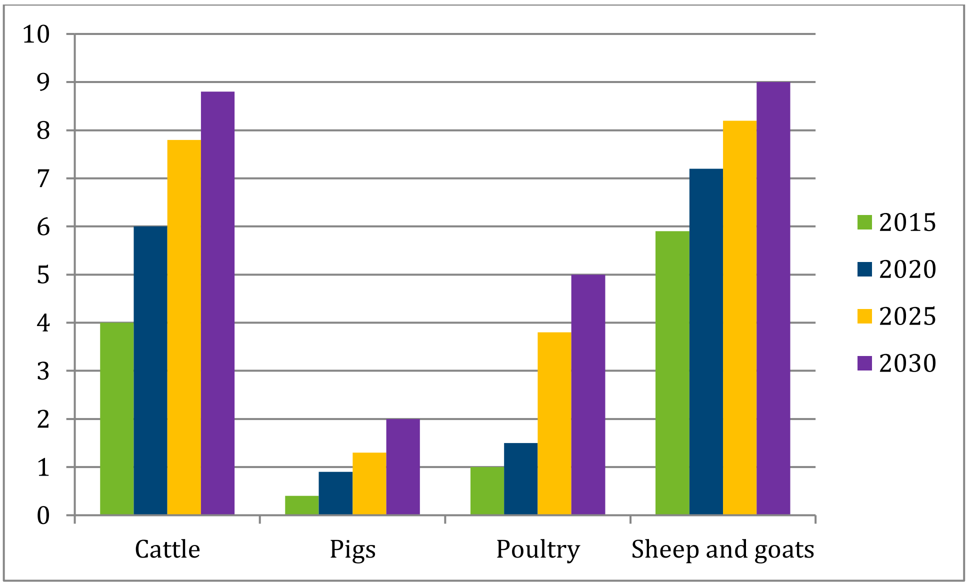
Figure 9: Increase in organic livestock production by species 2015-2030, in % of livestock production.



(Data from European Commission 2019a)

The non-GMO and organic food market segments are increasing their relative shares of the European food market. Growth in exports of organic food to particularly China is a significant driver for increasing the EU production of organically farmed products including milk and meat. It is therefore obvious that the need for organic feed is growing and that Europe will have to find ways to meet this larger demand. Prices on food items labelled as organic or non-GMO are more expensive than the prices on comparable conventional foods, hence the value chains from farm to food of non-GMO and organic products are regarded as high-value chains. This situation could motivate the development of local or regional legume- or pulse-based feed value chains.

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3.2.3 Aquaculture production

In Europe, aquaculture production can be sea-based as for example salmon production along the coastlines of Scotland, Faroe Islands and Norway or, production of seabass and seabream in the Mediterranean Sea. Aquaculture production can also be based on fresh-water systems for production of carp (particularly in East Europe) or trout (Denmark and Germany). The newest technologies for aquaculture production are recirculated land-based systems where the water is cleaned and nearly 100 % re-used. This kind of re-circulated production system poses high demands on the digestibility of the feed to reduce the excretion of nitrogen in order to reduce water pollution. Therefore, formulators of fish feed must produce food with adequate supplies of highly digestible nutrients including essential amino acids and ensure that as little nitrogen as possible will end up in the water. Faba beans could a sustainable alternative to replace fish meal in such diets, as illustrated here in section 5.1. In countries like Denmark and Germany there are production systems for organically farmed trout and salmon. An essential requirement for organic aquaculture systems is the use of organic feed. Currently, feed formulators comply with this requirement by using organic soya bean cakes.

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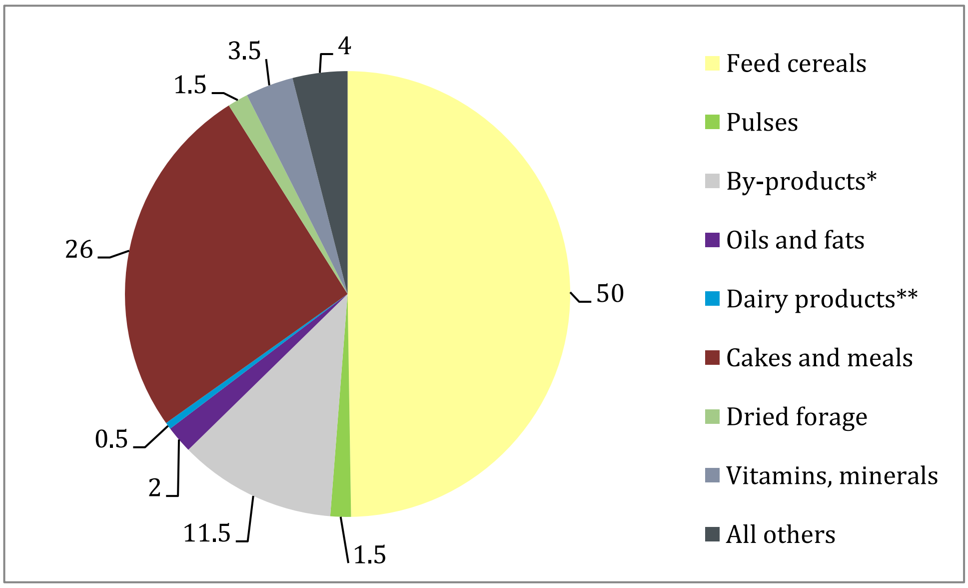
4 Organising the value chain for the feed industry

4.1 EU Market for grain legumes as feed

By 2017, the EU industrial compound feed production amounted to 159 million tons in contrast to 156 million tons in 2016: an increase of ca. 2 %, which is in line with growth rates for the previous years. To produce 159 million compound feed, the European feed industry made of use many types of feed materials (Figure 10). Feed for poultry account for 35 % of the European feed industry's production, pig feed for 33 % and, feed for ruminants for 28 %. Feed for poultry and dairy cows show the strongest growth rates (European Commission, 2018 building on data from FEFAC[3]). The European feed industry is expected to show modest growth rates of 0.3 % annually in the coming years; this is anticipated to leave only limited growth prospects for European plant proteins targeted at the conventional compound feed industry.

Figure 10: Materials used to produce compound feed for farm animals in the EU, 2017 (in % of materials used, as calculated by FEFAC).



(Major N., 2018); Notes: *By-products encompass side streams from the food industry and manufacturing of bioethanol; ** Dairy products are mainly skim milk powder.

[3] FEFAC: European Feed Manufacturers Association, www.fefac.org

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As shown in Figure 10, the use of grain legumes in 2017 accounted for 1.5 % of the materials used by the European compound feed industry (an estimated volume of 2.4 million tons). This contrasts with the situation in 1990, when grain legumes accounted for 5 % of the materials used by the EU feed industry. In 2017 the compound feed industry used 41 million tons of cakes and meals (i.e. meals from soya beans, sunflowers and rapeseeds after solvent-based oil extraction) as protein sources. By including cereals, co-products (e.g. potato protein or maize gluten), cakes and meals, and dried fodder (particularly alfalfa) as sources of proteins, the EU currently stands at a self-sufficiency rate for protein of ca. 60 % (Kumprecht, 2018). Due to an increasing livestock production in the EU, demand for protein feed will increase. It is forecasted that by 2030 EU will need to import 50 % of the oil seed meal needed to feed the livestock (European Commission, 2019a).

Grain legumes complicate feed formulations, as revealed in stakeholder consultations (Appendix 2). This is because when new raw materials e.g. peas and faba beans are used in feed, additional costs for building new silos, formulation of recipes and other costs are added to the price for the crop. Transaction costs for peas add 12 % to the feed price due to costs related to low volumes, difficulties resulting from lack of quality standards and due to incoherent value chains. Production and handling of organic legumes is even more complicated due to technical constraints and regulations and the lack of investments in facilities for collecting and processing organic legumes for feed. In addition, grain legumes contain anti-nutritional factors such as enzymes (e.g. protease inhibitors, saponins and tannins etc.), that if exceeding specific thresholds in total ration will inhibit intake, digestion and consequently animal productivity. This is limiting the use of grain legumes in compound feed. Because of their anti-bacterial, anti-inflammatory and anthelmintic effects, below these thresholds, most anti-nutritional factors may in fact exert positive effects. Such potential benefits of grain legumes in animal production systems have not yet been assessed in full.

The European production of soya beans is increasing (Figure 11), and awareness of sustainability issues are evident from the EU feed manufacturing industry association FEFAC as well as private initiatives. FEFAC has published guidelines on sourcing of sustainable soya as a measure to counterbalance the negative issues related to growing soya beans in the Americas. In FEFAC's guidelines is stated that to be certified as "responsible soy" the farmer must comply with factors such as local legislation on land management, deforestation, local biodiversity conservation, and labour rights. It is perceived that these guidelines are targeted at farmers in third countries (FEFAC, 2016). Private initiatives from European organizations address soya bean production by building on non-GMO and sustainable farming practices as explained below.

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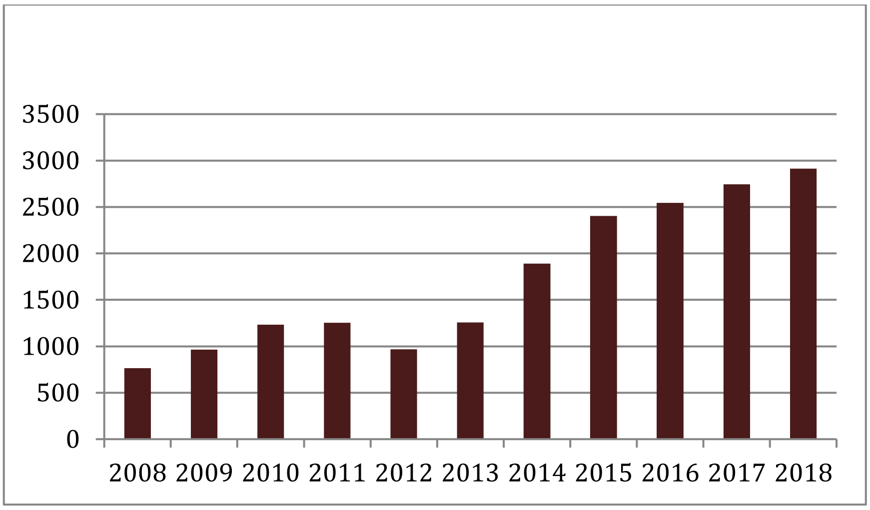
Figure 11: Development in the European harvest of soya beans, 1000 tons (y axis) over the years 2008-2018.



(Data from Eurostat, 2020)

The organisation Terres Univia in France has published a charter for uniting the value chain for more sustainable soya beans production in France (Terres Univia 2018). The charter addresses the French origin of the crop; traceability, non-GMO cultivation, and sustainable farming practices. In 2017 more than 141,000 ha were planted with soya beans in France and the Charter framed the French production of soya beans.

An important initiative for motivating soya bean cultivation in Europe is the non-profit organisation Donau Soja. The organisation was founded in 2012 in Vienna (Austria) with the goal of promoting a sustainable and European protein supply. Donau Soja has instigated its own standards for certification of sustainable soya beans building on non-GMO cultivation and an environmentally and socially responsible farming practice. The organisation counts 280 members and spans the entire value chain (farm to food store), food processors, agricultural traders, the feed industry and organizations such as WWF and Greenpeace. Figure 12 illustrates how the organisation has developed from a local to a European initiative. Donau Soja interlinks the Danube region with new economic perspectives, offering economic opportunities and stimulus for all European countries and helping member businesses change the market towards an increasing demand for sustainable and European protein supply (Donau Soja, 2020).

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Figure 12: The development of the non-profit organisation Donau Soja.

Retrieved from https://www.donausoja.org/en/about-us/the-association/ , March 2020

The main drivers for the organic and non-GMO sectors are consumer demands for livestock products where animal welfare, environmental impact and type of farming system is at the centre. For example, in Germany in 2012, 9 % of the cattle feed was labelled as non-GMO and, by 2017, this share had increased to more than 40 %. The German label is recognised as the VLOG certification (*"ohne Gentechnik"*). Similar development patterns are seen in Austria, and the share of the non-GMO feed is 85 % for poultry feed and 56 % for cattle feed. From an EU perspective the market share for non-GMO feed is estimated at 19 % for poultry, 5 % for pork, and 8 % for cattle. Across animal categories the market share for non-GMO feed in the EU is 11 % (EC, 2018). The production of organic compound feed is estimated at 2-3 %[4] of the European compound feed industry, thus, a feed production volume of 3.2-4.7 million tons. Hereto should be added green fodders such as organic alfalfa and clover. The growth in organic dairy farming also favours grass-based production systems and on-farm feed production to meet minimum on-farm feed shares. These elements are central to organic farming (EC, 2018).

[4] Figure estimated by IFAU based on the share of organic livestock production

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4.2 Price mechanisms for protein feed

The EU compound feed market is highly price driven. Livestock farmers are looking for 'value for money' in the sense that the feed should provide the best nutrition at the lowest price. In this perspective large volumes of commodity ingredients are sourced by the feed companies from European and foreign suppliers. Examples of commodities could be soya beans, soya bean meals or sunflower or rapeseed cakes. Commodities are traded on international trading terms and prices are set in contracts, as spot market prices or using futures.

Prices are set at Commodity Exchanges such as Chicago Board of Trade (CBOT). Commodity prices are available to buyers and sellers from international trading platforms as for example Bloomberg. The example provided in Figure 13 shows that the market price of soya bean meal had declined by 1.09 % or 3.30 US$ per ton between two days of trading to 299 US$ per ton. Figure 13 also shows that soya beans are traded in bushels and that the price during the same two days had declined by 10.75 US$ per bushel; that is a relative drop in prices of 1.25 %. The examples illustrate the dynamics in the protein market and therefore also the challenges of knowing the right time to buy or sell. The positive aspect and an important one for facilitating trade across borders are the transparency in current prices.

Figure 13: Example of commodity prices from the Chicago Board of Trade (CBOT), as published by Bloomberg, March 2020. Bu = bushel. Pink- and green-highlighted values denote prices with have declined or increased/unchanged, respectively

	INDEX			
COMMODITY	**UNITS**	**PRICE**	**CHANGE**	**%CHANGE**
Corn	US$/bu.	365.75	0.00	0.00%
Wheat	US$/bu.	506.00	+0.50	+0.10%
Oats	US$/bu.	268.25	-6.75	-2.45%
Soya bean	US$/bu.	848.75	-10.75	-1.25%
Soya bean Meal	US$/T.	299.50	-3.30	-1.09%
Soya bean Oil	US$/lb.	26.37	-0.01	-0.04%

(https://www.bloomberg.com/markets/commodities/futures/agriculture, March 15, 2020)

In reality, formulation of diets for animals is an optimisation of the combination of nutrients and price for nutrients in such a way that the diet will meet the nutritional requirements of the species. Because of the importance of the amino acid supply and the digestibility of the protein in animal nutrition, these factors determine for the price of the protein. Soya bean meal is a nutritionally high-quality feed as it provides all essential amino acids at a competitive price, and the feedstuff is available year-round in large quantities. Therefore, **soya beans meal is used as reference point** for comparing prices on protein feed, often referred to as "soya bean equivalents".

The protein available in the market should be regarded as tons crude protein, not tons of protein feed. For example, faba beans have a protein content of 23-29 % whereas soya bean meal has 44-48 % protein. Soya bean meal is traded as a standardised commodity priced according to protein content whereas grain and fodder legumes in general are traded according to market demand.

Table 4 shows examples of how protein is priced according to the content of essential amino acids (content of digestible lysine). It is seen that soya bean meal (standard of 50 % protein) is the cheapest source of digestible lysine (14 EUR per kg), and that makes this feedstuff attractive to farmers. Table 4 also shows that lupins could be a competitive source of lysine (priced at 22.89 EUR/kg) which is about the same level as the price for potato protein (23.77 EUR/kg) and rapeseed meal (21.56 EUR/kg). In this perspective lupin could be an interesting source of protein for the feed industry. This will be expanded in section 5.2.

Table 4: Prices on protein feedstuffs vs. prices on digestible protein, 2018.

Feedstuff	Crude protein, g/kg	Digestible lysine, g/kg	Digestible lysine, EUR/kg
Potato protein	803	58.46	23.77
Soya bean meal, 50% protein	**470**	**25.50**	**14.71**
Rapeseed meal	340	11.83	21.56
Sunflower meal, 35 % protein	280	8.06	26.05
Maize gluten meal	600	8.67	95.16
Lupin	**310**	**15.29**	**22.89**

(Kumprecht, 2018)

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The pricing mechanism illustrated above is also evident in research carried out in Denmark on organic faba beans. Interviews with feed companies producing organic compound feed for pigs reveal that prices of organic protein are based on the protein content. The examples provided in this section show that it is not straight-forward to compare prices on protein feed.

4.3 Buying behaviour of feed companies

Feed companies buy grain legumes for use in the manufacturing of compound feed. The companies buy such commodities from traders and directly from farmers. As feed companies are manufacturing feed year-round, the companies depend on constant supplies of ingredients. Stakeholder consultations have shown that companies use spot-market prices when buying from farmers, particularly during the harvest season. This means that the farmer will sell the crop and receive the current price. Another approach is for the farmer to store the grain legumes on the farm and sell it at (potentially better) prices during the winter and spring season. Widely used ingredients in feed mills like soya bean meal are procured from traders and wholesalers. The deal could be based on spot-market terms, futures or other contractual agreements.

Companies that are specialised in processing and drying fodder crops are the most important buyers of legume crops like alfalfa and clover-grass. Countries such as Spain, Italy and France have large-scale industries for producing dried alfalfa products (bales and pellets) for the feed market. The most common arrangement is that the farmer produces the fodder crop on contract for the processing company.

4.4 Logistics and storage infrastructure

There are many options for storing grain and fodder legume crops. A study from 2017 shows how storage capacities for cereals, oilseeds and protein crops (COP crops) vary among value chains actors (European Commission, 2017a) (Figure 14). On-farm storage plays an important role as it accounts for 40 % of the European storage capacity. This could indicate that a large share (30-50 %) of the COP crop is for on-farm use (Sepngang et al., 2018), as also stated in stakeholder consultations. Having such a relatively large storage capacity on farms could also be a determinant of farmers' behaviour in the value chain in the sense that, farmers sell the crop when prices are right and not only during the harvest season. This behaviour is well-known to occur for selling cereals and oilseeds, but it is not known how widespread this behaviour is for grain legumes.

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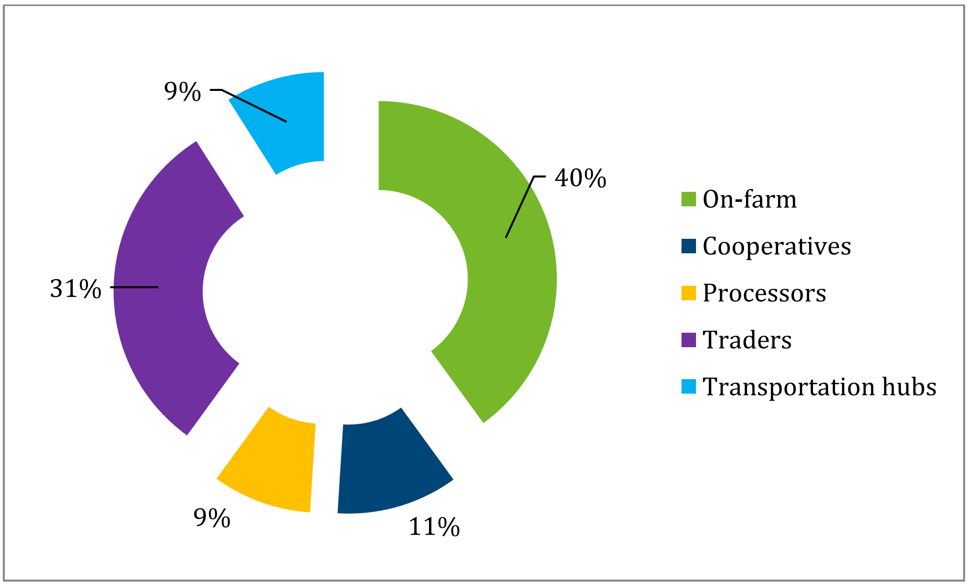
Figure 14: Storage capacity by value chain actors, 2017 (in % of EU storage capacity for cereals, oilseeds and protein crops).



(Based on European Commission, 2017a)

Traders hold one third of the storage capacity for COP crops (Figure 14) and transportation hubs hold 9 %. The study concluded that storage capacity at transportation hubs was increasing to hold larger volumes and investments were made to increase the speed of the COP handling (European Commission, 2017a). This is pointing at expectations of increasing trade with grains, oilseeds and protein crops as imported goods to the EU and intra-EU trade. Storage capacity at processing plants (flour mills, oilseed mills and feed mills) only account for 9 % of EU storage capacity. Yet, these companies can handle large quantities with a relatively limited capacity due to a just-in-time delivery system making these companies dependent on constant deliveries to their plants.

Logistics are important for moving the crop from field to market. Road, rail and inland waterways[5] play different roles in the transportation of COP crops. Mostly, the various means of transportation are used in combination. Inland waterways and railway handle almost all long-distance transportation of crops, 60-70 % and 30-40 %, respectively. Trucks play a marginal role in long-distance transportation of COP crops, and trucks are only used for long-distance hauls if railways or inland waterways are not available. Greater flexibility and density of the road network favour trucks

[5] Inland waterways: Rivers and canals in mainland Europe

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in short-distance transportation, especially for moving crops from the field to local users or to logistical hubs. It is not possible to say how exactly grain legumes are transported as commodities but the findings from the study (European Commission, 2017a) about cereals and oilseed crops provide information about the logistics for moving crops. According to stakeholder consultations and presentations from the Legume Innovation Network workshop meetings (Appendix 2) it is perceived that the general picture is also valid for grain legume crops.

At aggregate level, there is no shortage of storage capacity for cereals, oilseeds and protein crops in the EU (EU Commission, 2017a). Yet, value chain actors do invest in storage capacity for crops as there may be local concerns. There seems to be three significant patterns of investments:

1) agribusiness cooperatives investing in technological upgrades and rationalisation of existing facilities;

2) companies in the processing industry including feed mills invest in rationalisation of existing facilities in Western EU countries, and in more storage capacity in Eastern EU countries; and,

3) export-oriented traders at transportation hubs invest to increase capacity and speed of handling crops – most relevant for EU exports of cereals.

Business like processors and traders seem to make use of own funds and venture capital for investing in storage capacity for crops. Public funding via EU Rural Development programs has been used for investments in on-farm storage capacity and some investments made by agribusiness cooperatives (EU Commission, 2017a).

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5 Innovative approaches using fodder- and grain-legumes for feed

This chapter will explore innovative approaches for using, growing and marketing of grain legumes for feed. The examples provided will address technical challenges, cultivation aspects, supply chain challenges, and market opportunities.

5.1 Using faba beans for as feed for salmon

BioMar is one the three largest manufacturers of feed for aquaculture in the world and produces 1.2 million tons of feed for aquaculture per year. BioMar has production facilities in 15 countries across the world, and hereof 8 factories in Europe and Turkey. Today, 1 of every 5 European farmed fish is fed with BioMar feed. Currently more than 50 % of the global fish consumption comes from aquaculture production. The FAO has calculated that every year global aquaculture production must be increased by 23 million tons to meet the global demand for fish and seafood by 2030. A general calculation shows that 100 kg of feed would produce 56 kg of meat from fish in contrast to 22 kg of poultry meat and 4 kg of beef. Providing fish feed to meet this huge demand must build on a sustainability strategy and therefore BioMar has turned the attention to using grain legumes in diets for fish.

Fish meal has for many years been the main ingredient in feed for aquaculture, but fish meal is regarded as a limited resource due to over-fishing of fish stocks. Therefore, other feed sources are used in diets for aquaculture productions, especially to provide protein and essential fatty acids. During the last 20 years the use of proteins from soya beans meals or maize gluten and vegetable oils from soya beans and rape seed have become increasingly used as ingredients in diets for fish (Figure 15). BioMar has taken to use faba beans in the fish feed. In 2015, BioMar used 2,000 tons of faba beans, and by 2019, the volume has increased to 10,000 tons. Furthermore, the company turned to use only dehulled faba beans as of 2017 to increase digestibility of the feed (Vestergaard, 2019).

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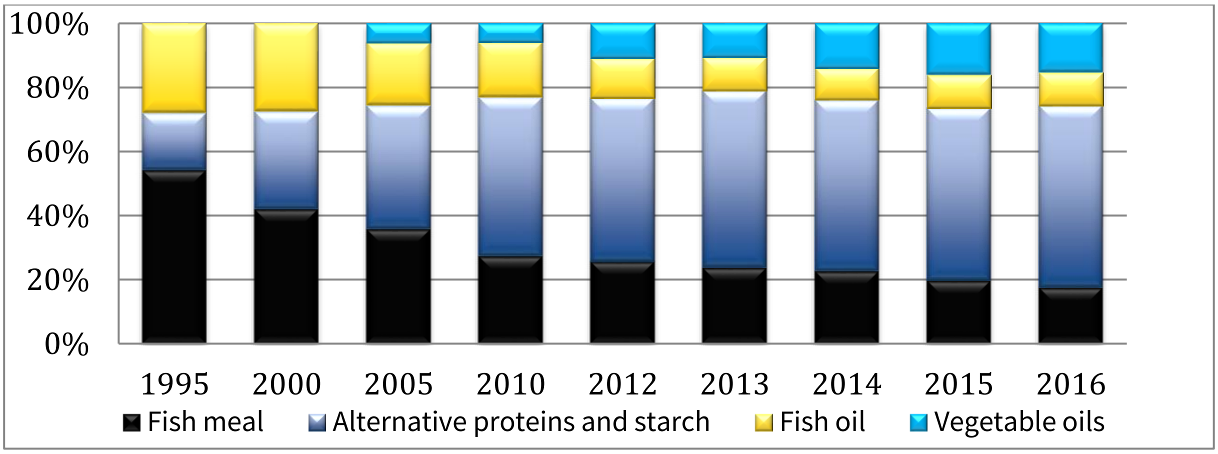
Figure 15: Development in use of ingredients for fish feed, in % of diet composition.



(Presented by BioMar based on data from project BioSustain, 2018)

The experiences from using faba beans can be summarized as:

- faba beans is a local (European) and sustainable protein source;
- faba beans can be stored and processed;
- protein from faba beans has a low carbon-footprint compared to other protein sources;
- diets with faba beans have good digestibility with farmed fish and demand is increasing.

Of major concern for expanding the use plant proteins in fish feed is the availability of grain legume crops. As the company has contracts for delivering large volumes of feed to major producers of aquaculture there is a need to guarantee the supply of ingredients for the agreed diets. Consider for example the supply of feed for salmon in Norway or Scotland and need for ensuring proper nutrition in scales sufficient to meet this demand. Here, uncertainties about availability of European protein sources can become a serious issue as lack of grain legume crops may lead to the need to reformulate diets. This could result in changes in prices on the feed as well as have an impact on the productivity of the fish farming systems. Rooted in the concerns related to the volumes needed to feed the growing aquaculture sector makes a company like BioMar an important player for creating market demand for European grain legumes. The example also demonstrates the impact that comes from scale and the benefits following from being at the forefront of producing and marketing more sustainable animal diets.

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5.2 Lupins as a new source of feed for shrimps

Whiteleg shrimps (*L. vannamei*) are produced in aquaculture systems in many parts of the World. Shrimps are typically fed a diet high in fish meal with up to 50 % inclusion rates. In recent years, feed formulators have reduced the inclusion rate of fish meal and replaced it with soya bean meal. Shrimps can grow well on such diets, but issues related to loss of biodiversity and civil rights abuses linked to logging of rainforest and loss of habitat in cerrado regions, plus consumers' concerns regarding GM soya bean has forced the feed industry to look for alternative plant protein sources.

Experiments have shown that lupin digestibility exceeded that of soya in salmon. Trout, turbot and seabass (species common in European aquaculture) were found to grow well on extruded lupin seed meal. Research has shown that 50 % of the fish meal used in diets for Whiteleg shrimps could be replaced by lupin meal (Hoerterer et al, 2016). Recent feeding experiments carried out at the Alfred Wegener Institute in Germany aimed at testing the inclusion rate of lupin kernel meal in diets for Whiteleg shrimps. The German experiment demonstrated that the optimal inclusion rate for lupin kernel meal was 100 g per kg feed for Whiteleg shrimps and, that including 10 % lupin kernel meal in the feed had an immune-stimulating effect on the shrimps. If inclusion rates were higher than 10 %, the growth performance of the shrimps was reduced (Weiss et al., 2020).

Taking the findings from the Alfred Wegener Institute into a global context, it is evident that the potential for including lupin kernel meal into diets for shrimps point to an up-tapped potential for using lupins in the aquafeed industry, extending the use of lupins to crustaceans, especially shrimp will allow access to the enormous Asia-Pacific aquaculture market. This statement is supported by findings from Western Australia where it has been documented that commercial fish feed manufacturers use lupins in feed for salmonids and shrimps today (GRDC, 2018).

5.3 Using faba beans in beer brewing provides a new source of protein feed

Brewing beer could be regarded as a separation process that aims to utilize the starch fraction to produce alcohol and subsequently finding a use for the spent grains; the latter being a protein-rich fraction. Despite positively selecting raw materials with a high carbohydrate content a significant portion of co-products enriched in protein, fiber and oil are still generated with the main co-product, known as 'spent grain', consisting of the grain material which has not been solubilized during the mashing process.

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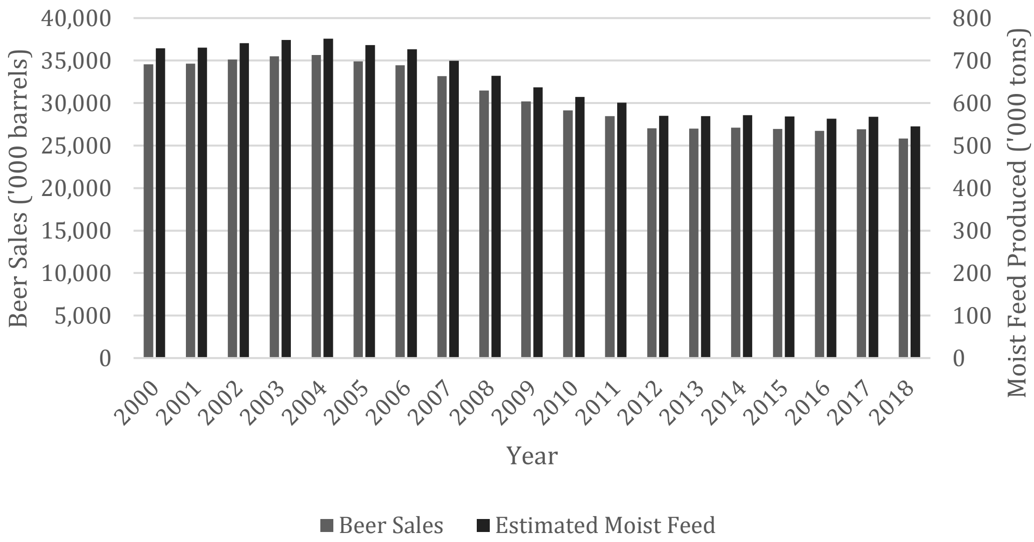
Despite the extraction of starch and other materials into solution it is typically said that one ton of malt processed in a brewery yields 1.1 tons of spent grains due to an increase in moisture content (Crawshaw, 2001). Utilising beer sales data it is possible to estimate the output of moist feed from UK breweries (Figure 16), averaging 563,000 tons a year over the last 5 years.

Figure 16: Beer and moist feed brewing coproduct production in the UK.



Beer sales extracted from BBPA data (2018). Moist feed tonnage is based on estimated malt use, excluding yeast, utilising a ratio of 47.4 barrels of beer produced per tons of grain; ratio calculated using historical data published by Brewers' and Licensed Retailers' Association (BLRA 2018). 2018 data extrapolated from Q1 and Q2 sales.

The specific composition, including nutritional value, of brewery by-products is dependent on the raw materials used and production method applied. In 2000, malted barley accounted for nearly 91% of the raw materials (BLRA 2018) used by UK breweries (discounting sugar) with the remaining materials (70,000 tons) being referred to as adjuncts. Adjuncts are alternative starch sources which may be selected due to them offering a greater extract potential, and therefore alcohol yield, at a lower price, or to positively impact beer quality. Typical adjuncts include raw barley, wheat, maize or rice grits but pulses can also be used. Utilizing pulses, such as faba beans, as an adjunct in beer production offers the opportunity for an environmentally sustainable raw material to the brewery industry whilst also improving the nutritional value of the spent grain. The inclusion of faba beans as a brewing adjunct does not negatively impact the taste or acceptability of the resultant beer (Black et al., 2019).

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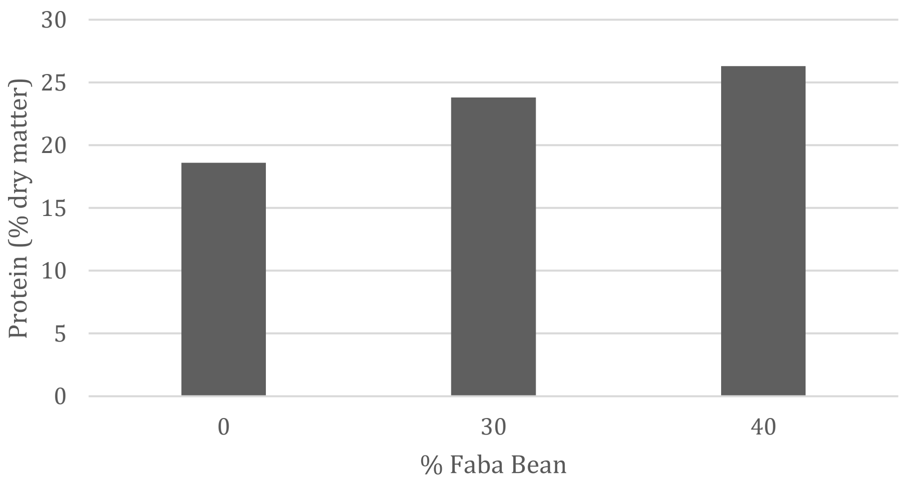
Through commercial scale trials at Barney's Beer, a microbrewery in Edinburgh, the feasibility of including faba bean flour as an adjunct has been demonstrated and a direct correlation with spent grains protein content was found (Figure 17). The aforementioned 563,000 tons of moist feed produced from breweries annually in the UK equates to nearly 19,000 tons of protein (assuming 18% dry matter, 18.6% protein per Barney's Beer data). Trials also showed an increase in spent grain dry matter with increased faba bean inclusion (18% with 0% faba bean, 25% with 40% faba bean flour) likely due to the increase in raw material required to counteract the lower faba bean starch concentration.

Figure 17: Impact of faba bean adjunct on spent grain protein content. For each beer produced, 0, 30, or 40% of the malted barley typically used has been replaced with milled faba beans.



(Black et al., 2019)

Considering this increase in dry matter, but not the potential increase in total tonnage produced, if all breweries in the UK moved to replacing 40% of their malted barley with milled faba beans this would result in an increase of 96% in protein yield in the spent grains to 36,869 tons (Black et al., 2019). Feeding trials with broilers have been carried out and the results are expected soon. Preliminary findings indicate that the broilers' feed intake was slightly less than that of broilers offered soya bean meal or milled faba beans. Researchers expect that the results from the feeding trials will prove that broilers intake of feed will not be constrained by the inclusion of faba beans in the spent grains (Houdijk, 2020). The example illustrates how a new perspective on using pulses, here for the brewing of beer, can improve the nutritional content of a by-product to make the spent grains a valuable source of feed protein.

5.4 Growing soya beans in the Netherlands

Soya beans are a new crop to Dutch agriculture. To explore how to grow this crop under local pedo-climatic conditions, the Wageningen University has planted conventional and organic soya beans for food and feed use in experimental fields in Flevoland province. The experience gained so far (1-2 cropping seasons) are that: soya beans can be planted early May into flat soil-surface so also the lowest hanging pods can be harvested by using a “normal” combine harvester. Being a new crop to Dutch farmers, there is no infrastructure and a market for Dutch-grown soya beans does not yet exist. This must be developed through collaboration involving farmers, seed providers, value chain actors and research. Soya bean is regarded as a crop that could be attractive for Dutch farmers as the current price is above the price for winter wheat. For cultivating soya beans there is no definitive need for fertilizers and the crop closes fast, this reduces the weed pressure. The first organic soya bean crop was harvested in 2017. The yield from the trials in Flevoland indicates that a crop yield of around 3 tons per hectare (dried soya beans) may be expected. A major challenge for new growers of soya beans in the Netherlands was to identify the variety that would best meet the local soil and weather conditions. The right variety was identified from Austria (Hamann, 2018).

This example from Flevoland shows the need to take all major aspects of growing a crop into account if a new crop is to gain attention from farmers. Especially should be noted the importance of the right variety, the attractiveness of the crop to the farmer and the need to develop a new value chain.

5.5 Increasing cultivation of organic grain legumes by collaboration

The most used protein source for organically farmed pigs is organic soya cakes. It is a requirement in organic farming that at least 20 % of the feed consumed is produced on the farm or locally. Therefore, it is relevant to investigate the potential of using organically grown grain legumes (peas, faba beans and lupins) for pigs. In Denmark the area under organically farmed grain legumes has doubled from 8,705 ha in 2016 to 15,685 ha in 2018 (Lambertsen, 2019), yet mixed crops such as peas/barley or lupin/spring wheat are still regarded as delivering on a low provision since these mixed-crops occupy only small areas. Organic farmers want to grow more mixed crops because of the over-yielding (greater yield per unit area, or ‘land equivalent ratio’), and the facilitative function of leguminous plants as a function of their capacities of biological nitrogen-fixation and to improve the soil microbiome and soil functions more generally. Legume-based crop-mixtures also serve as an integrated pest management strategy to help ensure crop protection. The approach also allows farmers (of mixed crop-animal) holdings to achieve higher levels of feed self-sufficiency and/or achieve higher commodity prices through offering very high volumes of aggregated crops. This was

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clear from a survey[6] carried out among Danish organic farmers. The farmers have learned that by working together it could become more attractive to grow mixed crops like pea/barley or lupin/spring wheat.

The benefits of pooling (or aggregating) crop grains from legume-supported systems mean that the large feed mills can offer suitably high prices, since there is greater consistency of product (and) in a large volume. A solution could be to invest in greater storage capacity so the crop from a farmers' network may be sold at the same time. Another solution is for the farmers to work together to elaborate a grain-legume based crop rotation plan as a group of farmers (as opposed to the operations of a single farm). Danish feed mills are interested in buying more organically grown grain legume crops: faba beans, peas, peas/barley and lupin crops. The feed industry points to four major hurdles for having more organic grain legume crops: crop volumes are too low; logistical challenges (long distances to processing plants); high price of Danish crops is contrast to imported protein feed; and, the need to separate organic crops from non-organic crops.

5.6 Bio-refining of clover-grass to make organic feed protein

As mono-gastric animals, pigs do not digest fibres very well. Therefore, the fibre and protein fractions need to be separated if pigs are to benefit from the high protein content in clover-grass crop mixtures. Research from Denmark has demonstrated that by using bio-refining techniques it is possible to produce a protein product with 50 % digestible protein and 45 % dry matter (Ambye-Jensen, 2019). The experiments were based on fresh-cut organic clover-grass (white clover). The clover-grass was fed through a screw press to make grass juice and the fibre fraction. A heat exchanger was used to precipitate the proteins, and after centrifugation the protein granulates was ready to be used. The remains from the centrifuge are known as the brown juice, and this is used for biogas. The fibre fraction is used as cattle feed.

The protein powder has been tested for use in compound feed by a Danish feed mill. It was demonstrated that it is possible to formulate diets for fattening pigs with an inclusion rate of legume-grass protein of up to 15 %. However, in principle and due to its beneficial amino acid composition, legume-grass protein could replace soya cakes in 1:1. Feeding trials of using legume-

[6] The survey was carried out with 20 organic farmers in February 2019 at the NutriFair exhibition in Denmark. The findings are in line with data from Organic Denmark and workshops organized as part of the TRUE project in Denmark 2018-2019.

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grass protein in diets for fattening pigs made it clear that pigs can thrive on this kind of protein, and that the higher the protein content was, the better the pigs seemed to digest the legume-grass protein. This indicates that organic legume-grass protein could be a very promising protein feed for pigs. Similar trials have been carried out with organically farmed layer-hens and the same positive findings were achieved.

The experiments from Denmark has led to a key finding that 1 ha of organic clover-grass can produce 1-1.2 tons of clover-grass protein (40-45 % dry matter in the protein product). The protein yield depends on several factors including type of clover-grass, the season, the efficiency of the techniques for bio-refining, and skills of the farmer (optimal harvest time and crop production) and the technician manning the bio-refinery. The estimated price on organic clover-grass protein is close to that of organic soya cakes so the system for making grass protein is currently targeted at the organic sector (Hamann and Gylling, 2020).

With the aid of Danish public funding at least two plants for making organic clover-grass protein will be established during 2020-2021 and both plants are headed by private investors. This opens for very interesting perspectives in Danish organic agriculture: the demand for clover-grass for processing could become a new business case for the farmer (e.g. growing an industrial crop); having more clover-grass in the crop rotation would benefit the environment due to reduced leaching of nutrients and provide nitrogen for improved soil fertility; and, as clover-grass is a crop that grows well in Denmark it is a sustainable basis for a locally produced protein feed. This is in-line with the principles of organic agriculture.

5.7 Networks uniting value chain actors: three examples from Germany

As part of the German Government's Protein Strategy (BMEL, 2016a), funding was made available to establish three demonstration networks for the grain legume crops, peas and faba beans, plus oleaginous grains from lupins, and soya beans. The aim of the networks was to stimulate knowledge transfer between research and practice; to organize demonstrations to encourage cultivation of grain legumes; to include actors from all steps of the value chains; and, to stimulate regional value chains to encourage market uptake of grain legume crops for food and feed. The soya bean network started in 2013, and in 2014 the lupin network was organized. The network for peas and faba beans followed in 2016.

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To support the build-up of knowledge, each network collects data from demonstrations farms within the network. This way, farmers are motivated to try diverse cultivation techniques and to monitor crop production, and this benefits a closer collaboration between research and practice. For example, in the lupin network data are collected from experiences of farmers and from analytical tests in laboratories that elaborate information on crop volumes, qualities, agronomic parameters (soil, climate, cultivation techniques and machinery), feeding value, costs and income, nitrogen fixation and impact on the following year's crop. As a function of the collaboration and data sharing, best practices for growing and using lupins can be identified and more-rapidly taken up by farmers (BMEL, 2016a).

5.8 Closing comments

This section has shown a selection of examples of how a new take on fodder- and grain-legumes could have significant impact on the value chains and demand for European produced protein feed. Yet, there may be major gaps to address if new feed sources should evolve into successful and sustainable value chains. New feed sources may not be available in quantities that meet the requirements of the feed mills, where demand for more than 10,000 tons per year is not uncommon. Another major issue is knowledge regarding the best practice for processing, storage or organization of logistics to achieve a coherent value chain (EIP Agri, 2018).

Central learnings from the examples are that collaboration, shared goals and financial investment in new capacities are fundamental for moving forward and achieving more fodder- and grain-legumes in EU feed value chains. It is also essential to be open-minded towards the opportunities in new protein feeds derived from processed fodder- and grain-legumes.

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6 Facilitating the EUs fodder- and grain-legume feed markets

6.1 Comparative assessment

In the previous sections, a range of factors have been analysed to understand coherences and mechanisms that impact the supply and demand for fodder- and grain-legumes in EU feed value chains. The emphasis has been on the role of fodder- and grain-legumes as protein feed. In this section, a comparative assessment will be drawn-out to show the challenges and opportunities of European protein feed (i.e. fodder- and grain-legumes) in contrast to soya bean feed. The comparison will address the demand and supply sides, in addition to factors that may facilitate market demand for European-grown legumes (Table 5).

Table 5: Comparative assessment of European fodder- and (non-soya) grain-legumes in contrast to imported soya beans.

Issue	EU legume-and grain legume-based value chains	Imported soya bean-based value chains
Mono-gastric animals (pigs, poultry and aquaculture) depend on highly digestible protein	Pulses and other (oleaginous) non-soya legume grains can be used for mono-gastric animals, ruminants and in aquaculture but lack some essential amino acids; Protein content in fodder- and grain-legumes is lower than in soya beans	Soya beans offer a highly digestible protein feed with an adequate amino acid profile. Soya beans can be used for mono-gastric animals, ruminants and in aquaculture.
Ruminants and horses need fibres in their diets	Alfalfa and clover are widely used in diets for ruminants and horses	Fibres from soya beans are not relevant
Feeding patterns	Using fodder- and grain-legumes in feed requires adaptations in diet composition to balance amino acid content.	Due to its good amino acid profile soya beans, soya cakes and soya bean meals are very widely used as protein sources in diets for animals
Context of protein supply	Area under pulses and other (oleaginous) non-soya legume grains in EU foreseen to increase. Regional producer organisations and networks are forming to cultivate and trade fodder- and grain-legumes; innovative approaches to process and use fodder- and grain-legumes.	Global and consistent supply of feed protein. Increasing global awareness of impact on environment from soya bean cultivation may challenge future production growth. Only limited innovation in "soya".
Market development opportunities	Exports of legume fodder to high-price markets in third countries; Expand production of organic soya beans;	Increase production of non-GMO and organic soya beans in third countries

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	Develop new value chains for new protein feeds (bean beer spent grains and bio-refined clover-grass protein);	
Setting the price	Price is related to the crop (i.e. price on faba beans or field peas). Prices are set locally between buyer and seller.	Soya bean price is related to protein content. Prices are set as world market prices. Soya bean price is used a "reference price" for protein
Organic production	Requirements for local (on-farm) production of feed. Legumes important for crop rotation patterns in organic farming. There is trust in EU organic label.	EU currently dependent on imports of organic soya cakes from China and Ukraine. Trust in organic certification is questioned.
Non-GMO farming	Fodder- and grain-legumes are non-GMO protein crops. Non-GMO food market developing in EU.	Non-GMO soya bean is available but must be kept separate from other soya bean types. Non-GMO soya more expensive than other (GM containing) soya bean sources.
Sustainability approach	Regional producer organisations and networks related to the specific crop drive the development.	Global Roundtable for Responsible Soya bean; FEFAC Guidelines for responsible sourcing of soya bean.
Availability	EU Pulses and other (oleaginous) non-soya legume grains plus fodder legume production is insufficient to satisfy current demand. Value chains for pulses and other (oleaginous) non-soya legume grains and fodder legumes are mainly local/regional. A large share of fodder- and grain-legumes is used on-farm.	Established and large-scale value chains ensure constant availability of big volumes of soya bean.
Value chain coherence	Low volumes de-motivate investments in infrastructure for storage and processing. No standards defined for pulses and other (oleaginous) non-soya legume grains or fodder legume crops. No European facility for trading fodder- and grain-legumes.	Soya bean trade is based on protein content = a defined standard. Large-scale storage facilities are established at logistics hubs and by processors. Feed companies and traders are established importers of soya bean.
Market transparency	Data on production and trade are available (FAO, Eurostat). Data on local prices are available in some cases.	Production and trade data (FAO, Eurostat, USDA), and prices (index mundi, Chicago trade exchange et) are available from several sources.
Logistics and transportation hubs	No dedicated transportation hubs for EU pulses or other (oleaginous) non-soya legume grains crops and fodder legumes. The hubs are mainly for local use, only smaller share of the grain legume crops are for intra-EU trade.	Investments in increasing capacity and handling speed at transportation hubs. Logistics for transportation of imported soya beans to all over Europe available and operational. Need to keep non-GMO soya bean apart from other soya bean crops.
Facilitating trade	Subject to rules on EU Internal Market and the EU Regulations relevant for markets,	Subject to international trade agreements as trade is mainly inter-continental. Regulating

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	feeds and standards as trade is mainly intra-EU. Regulating Authority: EU Commission	Authority: Multiple governments in agreement
Food-feed complex	Pulses and other (oleaginous) non-soya legume grains plus fodder legumes are mainly for feed. Legumes are also cover crops for environmental purposes and can be used for bio-based products. Stronger growth and awareness of pulses and other (oleaginous) non-soya legume grains for food than for feed.	Soya bean is an oil crop and soya bean meals and cakes are by-products from the oilseed crushing industry with largely only feed purposes. Increasing demand in food for meat alternatives and drinks made with soya bean.

(Own elaboration, 2020)

6.2 The demand side: animal nutrition

EU livestock and aquaculture production requires large volumes of protein feed with a good amino acid profile and high digestibility. Currently, ca. 20 million tons of soya bean meal and ca. 14 million tons of soya beans (for oilseed crushing[7]) are imported every year. In terms of global soya trade, the EU imports around 9 % of all soya beans traded and 31 % of protein meals. Overall, 95 % of soya imports are for animal feed (Friends of the Earth Europe, 2018). European livestock production has become highly dependent on soya bean feed. This is due to the lock-ins occurring from intensively rearing farm animals that require a nutrient dense diet to accommodate high-performance requirements such as gram growth per day per animal or kg milk per cow per day. Such indicators are clearly linked with the farmers' income in the sense that feed price, feed efficiency and farm gate price on milk, meat, eggs and wool should lead to a profit for the farmer. This expectation is a reasonable expectation for farmers of all cropping systems

Soya bean feed is today regarded as the most competitive source of feed protein due to its amino acid composition, digestibility, availability, prices and suitability for diverse animal species. Yet, other grain legumes can also be used to feed livestock and farmed fish, but this requires some adaptations of diets.

There are a range of benefits stemming from using leguminous plants and they are strongly linked to aspects of diversity. For example, legumes play an essential role in organic crop rotations systems as providers of nitrogen (natural fertilizer) and for improving soil quality (Zander et al., 2016). Another example is the options for using clover and alfalfa in conventional farming systems: the

[7] The by-product from soya bean crushing is the soya bean meal, and this is used for feed.

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crops can be used as 'green cover' to protect the soil and prevent leaching of nutrients from the soil. The crops can be harvested for making silage for cattle; grazing animals (ruminants and horses) can feed on these crops; and both crops can be used as green biomass for producing proteins, fibres, biofuels and other compounds. In contrast, soya bean meal and soya cakes, originally by-products from the vegetable oil industry, are standardised commodities. The innovation aspects of soya beans in a European perspective are linked to new collaborative approaches (for example the German soya bean network) and experimental cultivation in new pedo-climatic areas, as demonstrated by field trials in the Netherlands.

Furthermore, the amino acid composition of grain legumes does not match that of soya beans, hence compound feed made with grain legumes need to undertake additional efforts to balance ration amino acid content to meet the nutritional requirement of the animal. In many cases this means adding too much protein which eventually will be excreted by the animal. This has a negative impact on the environment. Feed mills would add synthetically produced amino acids to adjust the level accordingly, with emphasis on supplementation with methionine. This option is not allowed for organic agriculture, so diet formulation can be more challenging, especially if home-grown ingredients are to be used. An experiment from Denmark demonstrated that compound feed for organically produced pigs can be formulated with Danish-produced organic commodities (Table 6).

Table 6: Examples of commodity inclusion levels for compound feed produced for organically produced pigs in Denmark, 2019 (data for each commodity is % unless otherwise stated).

Ingredients (%)	**Organic compound feed for lactating sows**		**Organic compound feed for fattening pigs**	
Soya bean use	**Yes**	**No**	**Yes**	**No**
Organic grains	69.3	68.2	67.4	35
Faba beans	13	13.2	13	23.8
Lupins		4.8		
Rapeseed cake		5.1		8.9
De-hulled oats		3.1		29.6
Fish meal		3	4	
Soya cakes, Chinese origin	15		13	
Vitamins and minerals	2.7	2.6	2.6	2.7
Protein content (%)	15.01	15.87	16.82	17.48
Digestible protein, g/kg	123.7	129.5	141.0	146.0

(Lambertsen, 2019)

Table 6 shows that locally grown dietary provision is possible but may require more ingredients to compensate for not using soya cakes. It is also evident that the locally grown provision tends to

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have a total protein content that exceeds that other feed types such as soya cakes. This is because of the need to assure sufficient supplies of especially lysine, typically the first limiting amino acid (and elaborated by Leinonen et al., 2019).

Livestock and aquaculture production in Europe is expected to continue at the current volume for the coming years with slightly increasing productions. For conventional farming the feed supply situation could continue to build on imported soya bean feed but this is considered in conflict with the increased public awareness regarding sustainability issues of soya bean production in South America (Friends of the Earth Europe, 2018). The European feed industry has developed Guidelines[8] for how to source soya in a responsible manner and this could promote a more environmental-friendly and socially responsible approach to cultivating and using soya bean for feed. In Europe, the soya bean production has doubled in the last decade to 2.9 million tons (see this report section 1). Local and regional producer organizations headed by the Donau soya network has played an important role in organizing sustainable soya bean production and facilitating trade in Europe.

6.3 The supply side: providing feed

The provision of legumes (as green or dried fodder crops) plus other (oleaginous) non-soya legume grains for use as feed builds on integrated system with several actor groups involved. Farmers provide green fodder crops for use on farm either in the form of pastures for grazing animals or harvested crops to make silage, hay or delivered to drier facilities to manufacture pellets or dried legume crops. With 59.7 million ha of grasslands and pasture areas in the EU (European Commission, 2019a) there are vast opportunities for expanding the planting of legume crops such as clovers, vetches and alfalfa. Measures in European agricultural policies that supports planting of legume crops for feed or greening purpose are important to consider alongside the fact that farmers' income from growing legumes must be in line with, or better than, alternative options for crops or land use.

EU exports of dried fodder accounts for 18 % of global exports and represent 20 % of EU production of dried legume-based fodder (Agrosynergie, 2018). Exports of dried fodder is essential to countries like Spain (exports account for 75 % of the dried fodder production); Italy (70 %) and France (40 %). This means that value chains and processing facilities do exist, and that European exports are significant and competitive. This position should be developed further by promoting the cultivation

[8] FEFAC Guidelines for responsible sourcing of soy: https://www.fefac.eu/fefac-positions/sustainability/21551/

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of legumes for producing dried fodder for exports. This is an approach that would frame rural development, environmental benefits and provide incentives for growing legumes. Demand in major import markets like United Arab Emirates, China, countries in the Middle East and Japan is expected to further increase in the coming years due to an expanding local livestock production and climate challenges.

Learnings from organic agriculture show that as more farmers know about the benefits from growing fodder- and grain-legumes, the more willing farmers are to include these crops into the rotation systems (Lambertsen, 2019). The case study carried out about organic farmers in Denmark showed that clover-grass for grazing and silage production was used by all farms with dairy cattle. In contrast, organic farms with pig production were less inclined to grow legumes. When pig farmers were explained about the environmental benefits from having the legumes in their cereal-based organic crop rotations systems, they would take to grow legumes, too. This is evidence of the need for educating farmers about how to include legumes in crop rotations.

The EU compound feed industry is dependent on a large and consistent supply of commodities for manufacturing feed. This is also true for protein feed such as oils seed cakes and meals of which the feed industry used 52 million tons in 2019 (European Commission 2019a). The supply of oilseed meals is partly provided from the European oilseed crushing industry (30.5 million tons in 2019) and the remaining part (22.6 million tons) is imported. An effective system of import hubs and infrastructure for logistics has been established over many years to make this flow of protein feed and oilseeds possible.

The situation is different when it comes to pulses and other (oleaginous) non-soya legume grains. From stakeholder consultations and case studies it has come clear that the provision of such grains to the feed industry is a local or regional value chain in contrast to the international or European value chains for oilseed meals and cakes. There are several challenges for increasing the use of legume grains in compound feed. Logistics and storage facilities are not adequately developed to ensure a coherent value chain from field to process, and volumes are not great enough for the feed mills to invest in equipment to process pulses and other (oleaginous) non-soya legume grains. This means that farmers are struggling with low volumes, local production and trade aspects, and uncertainty about the crop size and farm gate price. For both the farmer and the feed mill this situation does not encourage the planting a larger area with legumes for feed. One action to stimulate the development and scaling up of the legumes-based value chain is to develop platforms for sharing market data and stimulating trade beyond the current regional approach.

Another aspect that needs to be dealt with if more grain legumes should be used for feed is their quality. The amino acid composition in pulses and non-soya legume grains is less favorable for animal nutrition in comparison to the amino acid composition in soya bean meal, and livestock producers demand nutrition, not legume grains. This is calling for improvement of the legume grain varieties currently used in organic and conventional farming to better match the requirements of animal nutrition.

In Europe there is a strong focus on using biomass such as crops or side streams (from agriculture or food processing) in new ways and feed has attracted much attention due to the volumes needed and the diversity of feeding strategies, the feeds used, and opportunities for developing new business ideas. Fodder- and grain-legumes are central in this regard. New ways of processing legumes (e.g. to produce protein from clover-grass) or to include pulses into existing processes (e.g. to use faba beans in the beer brewing process) provide evidence that innovative actions can lead to an enlarged supply of European produced protein feed. Added benefits of the new feed sources are that they lead to establishing new value chains, improved technologies plus new capacities, and hold potential for creating new jobs and new business models. These aspects relate to social policies and rural development (European Commission, 2017b).

The report has demonstrated from several case studies and experiments that the use of fodder- and grain-legumes for feed can be expanded if new ideas are put into practice. The example of using lupins for feeding shrimps could hold a vast potential for scaling up the EU production of lupins which is currently ca. 185,000 tons. If lupins also prove a valuable feed for farmed fish then there would be vast demand for investing in infrastructure and value chains, and farmers could then engage in growing lupins. The example illustrates the importance of having an application for a non-soya and still oleaginous crop that holds potential for scaling up to create the volume necessary for motivating investments in the value chain and market development.

Due to the higher prices in organic agriculture compared to conventional agriculture, the organic sector could be used as an 'experimentarium' for trying out new solutions. The main arguments being that the organic value chain actors are already focused on finding natural biobased solutions for food- and feed-systems, and that higher prices (or rewards for delivery of public goods), may motivate and facilitate an increased willingness to take on new ventures. As new ways to use fodder- and grain-legumes are developed, prices will tend to decline making such innovative solutions applicable to other farming systems too.

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6.4 Lessons from policy studies

During the last decade Europe has taken to a more formal approach to include soya beans in conventional and organic cropping systems. A cornerstone for developing the European soya bean cultivation was the foundation established by the European Soya Declaration (Donau Soya, 2012). On 17th July 2017, 13 EU countries signed the "Brussels Soya Declaration", submitted by Germany and Hungary on the initiative of twelve businesses spanning grain traders, feed manufacturers and retailers (Brussels soya Declaration, 2013). The main aim of this Declaration, in the near term at least, was to mitigate Europe's growing dependence on imported protein feed. Policy analysis carried out as part of the TRUE project have identified three policy action areas that need to be addressed if the European agri-food system is to increase the production and use of fodder- and grain-legumes for feed. These are:

1. increase investments in agri-food and -feed research and knowledge transfer to improve the competitiveness of home grown? protein crops and legume-based food products;

2. prevent the use of inorganic nitrogen fertiliser to create incentives for more fodder- and grain-legumes in crop rotations in conventional farming systems; and,

3. promote more sustainable diets for humans and animals by using public campaigns and activities for awareness rising by diverse stakeholder groups.

Overall, these three actions offer the best guidance to further develop pathways for having more fodder- and grain-legumes available for feeding purposes in the EU.

Ongoing European reliance on imported commodities such as soya beans for ensuring a sufficient supply of protein feed makes the European agricultural system vulnerable to potential trade disruptions. A policy that increases cultivation of a diverse range of legumes throughout Europe through price support would be strictly constrained by trade agreements in the World Trade Organisation (WTO). Such agreements facilitate imports through price and tariff reductions as well as the EU consensus on decoupled support systems. Due to such international trade agreements it is not possible to simply stop imports. Not least, as this would be regarded as violations of trade agreements. Figure 18 provides an example of how international trade agreements function in the case of soya beans.

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Figure 18: The USA-EC oilseed trade dispute.

In 1962, the American Soybean Association filed an Enforcement Action (Section 301), of the Trade Act of 1974 alleging that the European Community (EC) oilseed subsidies nullified and impaired the previous trade concessions, specifically the tariff-binding agreed in 1962. In 1962, the USA negotiated a zero-level tariff-binding on oilseeds, oilseed products and non-grain feed ingredients imported into the EC. During the Uruguay Round of Multilateral Trade Negotiations (MTNs), two bilateral trade agreements were negotiated to remedy the oilseed dispute. These agreements were the 'Blair House Agreement' and the '1992 Memorandum of Understanding on Oilseeds' addressed the oilseed trade dispute. Thus, a combination of EC policy reforms and trade agreements became the basis for resolution of the USA-EC oilseed trade dispute (Ames et al., 1996). The USA accounts for 52% of imports of soya bean to the EU, overtaking the volume supplied by Brazil. At President Trump's request, soya beans featured prominently in a plan for improving EU-US trade relations that were agreed on by the US president and the EU commission president Jean-Claude Juncker. Mr. Juncker pledged in a White House deal in late July 2018 that Europeans would buy more U.S. soya as part of a package aimed at averting threatening tariffs from Washington on U.S. imports of EU cars.

Based on insight described in Balázs et al., (2019), and Ames et al., (1996)

It could be argued that the high consumption of meat and dairy products by Europeans was made possible because of low prices of meat and dairy products due to intensive production systems and access to cheap feed (i.e. imported soya feed). In a policy context it is relevant to consider that consumers' choice of food is motivated by primarily the same factor as the farmer chooses feed, namely, *the price*. However, the impact of the choice is to be seen in two currently separated value chains, one characterised by large scale mono-cultures (even of legumes) at feed for livestock, and another characterised by diversification of crop species cultivated and agronomy used to generate for more-direct consumption (by humans) of the commodities generated and better known as '*farm-to-fork*'. Therefore, to encourage the shift towards farming systems based on European-sourced protein that is produced and consumed in a manner to benefit both environmental and personal health, the perspective of the value chain could be reconsidered as, '*from feed to food'*.

In November 2018 in Austria, the European Commission launched a strategy for the promotion of protein crop production and processing in Europe (European Commission, 2018). The publication was released after a public consultation phase and a series of meetings with invited experts specialising in innovations for the plant protein markets.

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According to the EU Plant Protein Plan (European Commission, 2018), results of the preparatory dialogues have highlighted claims that since the CAP reform in 2013, protein-crop areas and quantities produced increased considerably. Eurostat data show that the cultivated area for dry grain legumes and protein crops (including field peas, broad and field beans, sweet lupins, dry beans, other dry peas, lentils, chickpeas, vetches and other protein crops sown in pure crops or as mixtures with cereals harvested dry for grain) increased from 1.3 million ha in 2013 to 2.6 million ha in 2018, while production rose from 3.1 million tons to 6.2 million tons[9]. In the same period, cultivated area of soya bean increased from 0.43 million ha to 0.96 million ha[10], and production expanded from 1.2 million tons to 2.6 million tons[11].

In this sense policy measures for increasing cultivation of fodder- and grain-legumes in Europe have demonstrated impact. Yet, diverse stakeholder groups articulate different views on European production of fodder- and grain-legumes (Figure 19).

Figure 19: Policy challenges of meeting diverse stakeholder groups' requirements for sustainable agri-food systems.

The Plant Protein Strategy was positively received by many actors, although concerns were also raised. For example, Copa and Cogeca, while welcoming the strategy, argue for further necessary policy changes, such as increased consistency of different EU policies, research and innovation targeting protein crops, more reliable contracts between crop producers and livestock farmers, increased support for protein crop producers under the CAP to secure farmers' income (as VCSs are considered only as a short-term solution), and a targeted policy for crop-based biofuels to rebalance the protein deficit, among others (GOL(18)585). The feedstock sector calls attention to the need of further research on the nutritional value of different protein crops and warns that the willingness to domestically meet European demand for protein rich feed might result in unfavourable changes of current land use. Green NGOs, such as the Friends of the Earth and WWF, share social and environmental concerns over promoting soya bean production in the EU, arguing that by increasing soya bean production the unsustainable production structures (e.g. increased pesticide use, land grabbing, factory farming) will also be transferred to the EU. Instead, they advocate for a reduced level of production and consumption of animal products, and instead of promoting protein crops as animal feed, more emphasis should be placed on their human consumption and their environmental benefits.

(Based on insight described in Balázs et al., (2019))

[9] Dry pulses and protein crops for the production of grain (including seed and mixtures of cereals and pulses) by area, production and humidity (Eurostat)

[10] Rape, turnip rape, sunflower seeds and soya by area (Eurostat)

[11] EU Crops Market Observatory - Oilseeds and protein crops

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Several Member States (e.g. France and Germany) have formulated national plans for developing the plant protein sector. In the Netherlands, the Green Protein Alliance has formulated a strategy to motivate the transition from a meat and dairy based diet to a diet where plant proteins play a more central role. This food-sector pull strategy has an anticipated impact on the farm sector. The Dutch province of Flevoland has outlined a strategy for increasing cultivation and use of pulses and other (oleaginous) non-soya legume grains and fodder legumes for feed and food (Flevoland Government, 2018). Farmers are at the center of this strategy as farmers are regarded as the “vehicle” for initiating the Dutch protein transition to meet the growing consumer demand for plant-based foods. In this sense the Dutch protein transition is a food market pull strategy that eventually will increase the volume of leguminous plants cultivated in the Netherlands. Measures are available to connect farmers with processors and distributors (refer to section 5.4).

The Danish National Bioeconomy Panel has pointed to green resources to ensure a larger availability of feed protein; thus a feed-sector pull-strategy. The Bioeconomy Panel emphasizes clover-grass as a sustainable resource and, considers the environmental benefits that follows from reduced nitrogen-leaching from land covered with grass. The Danish implementation of the EU requirements for green cover crops will include the possibility of cultivating green protein crops such as faba beans, clover, alfalfa and grass and, in consideration of Danish environmental law. Furthermore, it is emphasized that technology plays a vital part for developing new value chains for green proteins. In this context technology encompasses machinery for agriculture, processing equipment for bio-refining and processing of pulses and other (oleaginous) non-soya legume grains plus fodder legumes, and better varieties of the plant species used for making green protein: e.g. clover, grasses and faba beans (National Bioeconomy Panel, 2018; see also Toma et al., 2020).

The examples above illustrate how Member States may have selected different approaches to promote the cultivation of leguminous plants in their agricultural systems. There may be many more approaches to stimulate cultivation and processing fodder- and grain-legumes for feed but common denominators are:

- collaboration within the value chain;
- realising the importance of technology and knowledge; and,
- building on the local context.

6.5 Conclusions and Recommended actions

6.5.1 Concluding remarks

The transition towards having more fodder- and grain-legumes in the European agricultural feed- and food-value changes is already underway. There is a need to steer the transition to encourage establishment of an EU agri-food system where production of feed protein (and other feed sources) is organised in a manner that favours the triple-bottom line of economic, environmental and societal impact. Therefore, the transition must take place at a pace that allows the value chain actors to get involved and, to adapt the production system and trade patterns accordingly. This should be rooted in local socio-economic and pedoclimatic contexts, but not necessarily limited to local value chains. Crop rotations are planned several years in advance, -and especially where crop choice is limited to genetically similar species - such as peas and faba beans for example. Where the potential accumulation of disease pressure means cultivation may be afforded only every fifth or even seventh year. Regulations at EU and Member State levels to protect the aquatic environment and water quality have framed agricultural production and land use for many years and will continue to show an impact on land use in the near future. Also, as the EU moves towards feed- and food-systems which are carbon neutral, environmental protection measures which also aim to limit to greenhouse gases will in future be allied to additional requirements that will ensure that soil qualities and functions are conserved or restored– or else that such damage is compensated for (in fiscal terms) (Helm, 2019).

No crop will be produced unless the farmer is motivated to grow the crop, and so an improved income either directly, or indirectly via improved gross margin (through lowered inputs for example), is fundamental. Crops are cultivated for a purpose, such as on-farm use, for sale or as part of a land management effort, and hence motivation for crop production must be regarded within a wider perspective including value chains and markets, environment, and social aspects. Innovative approaches to processing fodder- and grain-legumes for feed (and even food) purposes could form an integrated element in modern rural development as this would allow for new business models for farmers and promote the development of new (bio-based) value chains. Also, facilities for storing

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and processing fodder legumes contribute to the triple-bottom line[12] and could encourage legume cultivation on a larger area.

Fodder- and grain-legumes for feed is a comprehensive topic and, it includes much more than "pulses for compound feed". The opportunities for using legume grains, including pulses, in new diets for aquaculture and production of farmed fish or shellfish or, from expanding a current market-competitive position within dried green fodder should be high on the agenda of value chain actors, investors, and policy makers.

Changing established practices based on logics that do not pay respect the true costs incurred by all system components is especially challenging and poses a risk to system function and resilience. Such logic may be characterised by considerations such as, 'that soya bean meal should be regarded as the best and least expensive protein source'. Combating the barriers and limitations presented by such logic will require concerted effort. Here, giving supply chain actors access to independent knowledge providers and demonstration sites for new practices in cultivating, processing and marketing fodder- and grain-legume based products will form important elements. It is a well-known fact that if you 'see something working', then you are more willing to try this new approach. Also, that for behaviour change an alternative mode of operation must be invested in and repeated many times to become a new engrained practice. Different farming systems (e.g. organic farming, non-GMO farming systems, other) have their own perspectives on requirements for feed sources and feeding strategies. It takes nutrient-dense and complex feed to best care for high-yielding animals, so a change to another feed source may seem easy but does present significant risk and could have a significant impact on animal well-being, productivity, farm income and management.

The topic of legumes and their associated value chain opportunities and barriers is highly complex. Nevertheless, the topic holds an untapped potential for provision of animal nutrition, income generating activities, and measures for mitigating climate change. Finding solutions is challenging as many diverse and conflicting stakeholder groups have an interest. Yet, the way forward must be built on common understanding and a will to collaborate towards an agreed common goal. Ethically, this goal is to increase the supply of European-grown fodder- and grain-legumes for feed purposes, and to satisfy this demand in a manner that best benefits the well-being of the environment and its associated biodiversity, plus human life and in local- and global contexts.

[12] The triple-bottom line frames the economic, environmental and social impact.

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6.5.2 Recommended actions

In this following section there is a list of recommended actions targeted at facilitating the European market demand for grain legumes and fodder for feed. The actions are targeted at diverse stakeholder groups: policy makers, value chain actors, farmers and those in civil society.

Policy level

- Promote investments in infrastructure for facilitating trade and value chain development such as storage capacities, local cleaning and processing facilities for grain legumes. Build on a long-term perspective allowing time for a new value chain to develop and scale up.

- Align policy areas to combine cultivation of legumes with exploitation of market competitiveness and environmental benefits by for example supporting the development of processing facilities for dried legume-based fodder.

- Provide incentives that motivate trials and the establishment of new value chains for fodder- and grain-legumes targeted at the feed sector.

- Facilitate inter-regional and inter-local trade for specialty feed (e.g. organic pulses or new legume-based feed sources).

- Promote knowledge sharing among governments at more governance levels and across Member States. This could speed up the implementation of good practices from one region to another.

- Integrate diverse fodder- and grain-legume types into policies across value-chains for rural development. Also, add incentives for developing business cases building on fodder- and grain-legumes.

- Prioritize measures to improve education of current and future supply-chain actors to build knowledge about legume-based cropping systems as well as novel applications and business cases. Be sure to provide the agricultural advisory services with the relevant skills and knowledge.

- Provide support to improve the breeding and varieties of pulses and non-soya grain legumes to improve their value in animal nutrition and for their suitability for cultivation in European pedo-climatic zones.

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Value chain

- Encourage collaboration between business stakeholders (e.g. feed mills or machinery providers) and farmers to develop new value chains.
- Collaborate with farmers to develop local value chains or locally produced products e.g. types of feed, meat or dairy products.
- Develop a system to promote market access and transparency, maybe in the form of a "European Grain Legume Exchange".
- Engage with investors (small scale and large-scale investments) to encourage investments in production, processing and trade with fodder- and grain-legumes.

Farmers

- Collaborate to pool the grain legume crops for more attractive deals due from higher volume, quality and logistics.
- Collaborate with independent knowledge providers to learn more about how to increase incorporation of fodder- and grain-legumes into crop rotations and the use of fodder- and grain-legumes in diets for animal production.
- Collaborate with other farmers to develop crop ration plans for an area instead of for the farm.
- Take initiatives to develop local value chains and trading platforms.

Society

- Campaigns to raise awareness of consumers and other stakeholder groups about the non-monetary values following from having more fodder- and grain-legumes in European farming.
- Educate society about the legume-based farming systems including livestock production and, the benefits to environment, health and local economies.
- Encourage investments and access to funds to promote rural development, new business models, and to link society with farming.

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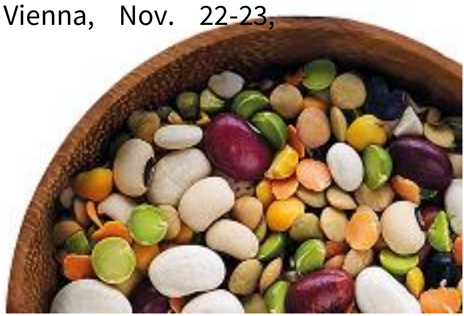

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Appendix I: Methodology

The analysis of the EU markets and value chains for fodder- and grain-legumes in feed is framed within an explorative research approach building on qualitative methodology and with added quantitative data. The explorative approach has contributed to maintaining an open mind towards diverse typologies of leguminous plants, livestock groups and feeding strategies. The research is carried out with a focus on the current situation and with retrospective findings to support arguments of how the demand and supply of fodder- and grain-legumes could be forecasted. This forms this basis for drawing up recommended actions that could be initiated by diverse stakeholder groups to encourage production and use of fodder- and grain-legumes for feeding purposes. The work is carried out with an EU perspective building on case studies and examples from Member States. United Kingdom is considered as an EU Member State at the time of writing.

The qualitative research has been centred round the question: **What are the challenges and opportunities for having more European produced fodder- and grain-legumes in the feed market?** The research question has framed a supply-chain-approach to accommodate the supply and demand situation; the infrastructure for production and trade; and finally, factors that impact supply and demand. The analysis is carried out with a focus on European fodder- and grain-legumes and, these findings are contrasted to the challenges and opportunities linked to soya beans as feed. The work has addressed conventional, organic and non-GMO value chains. The approach allows for including animal nutrition as part of the assessment of European pulses and grain legumes vs. imported soya bean feed.

The comparative assessment is elaborated to summarize the challenges and opportunities of European grain legumes and fodder, and imported soya bean feed. The comparative assessment is presented in a qualitative perspective with the purpose of highlighting the most critical and promising factors of the European and imported protein feed, respectively.

The report is prepared from desk research and field research. Desk research has comprised data gathering from reports, newsletters, statistics and academic papers. It has been a priority to gather data regarding fodder- and grain-legumes at European and national levels and, to collect both qualitative and quantitative data. Desk research has provided findings about production, trade, value chain structures, the feed industry, animal nutrition, and logistics and infrastructure. Another outcome from desk research is an understanding of the trading mechanisms for protein feed such as factors for setting the price, the demand criteria and purchasing strategies of feed companies, and the role of logistics and infrastructure for trade. In addition, desk research has provided examples of strategic measures and policies that could be implemented to promote more fodder- and grain-legumes into the feed value chains.

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Desk research has been supplemented by a comprehensive range of field research activities and experiments. Building on practical case studies, findings have been provided about barriers and opportunities for using pulses and other legume grains as feed, developing new value chains, or collaborative actions for encouraging cultivation and use of legumes in all their varied forms. The following case studies are included in the work.

- Using faba beans in beer brewing and the potential of the spent grain as poultry feed (UK).
- Using lupins in feed for white-leg shrimps (Germany).
- Using organic clover-grass to make protein powder (Denmark).
- Collaboration among organic farmers to improve market access (Denmark).
- Public funded networks to encourage value chain development for grain legumes as feed (Germany).
- Policies for promoting legume and grain legumes cultivation in the EU (Hungary).

To ensure the perspective of organic agriculture, a series of interviews with organic farmers in Denmark has been carried out. The interviews were conducted face-to-face by Organic Denmark. The scope was to identify farmers' motivation to include fodder- and grain-legumes into organic crop rotations, to learn about barriers from practice that could hamper the use of fodder- and grain-legumes as feed for organic pigs, and finally to identify potential pathways for having more fodder- and grain-legumes into organic farming systems.

Field research has included stakeholder consultations at more occasions. From the project's Legume Innovation Network (LIN) workshops in Peterborough (UK), Hohenheim (DE), Athens (GR), Nyborg (DK), and Porto (PO) important findings were retrieved from the value chain actors present at these meeting. The findings were discussed at the LINs by addressing the questions of "*How could we have more fodder- and grain-legumes into the feed value chains?*". And, "*What actions would you recommend for encouraging production and processing of fodder- and grain-legumes for feed?*". This way, findings from desk research has been validated with stakeholders in the feed value chain from farm to feed. The ISAB (International Scientific Advisory Board) members of the TRUE project have also provided their views on local, regional and international protein feed value chains through presentations and discussions at TRUE project meetings in Athens and Porto.

Attending EU workshop organized as part of the process leading to the EU Protein Plan has contributed with a European perspective and insights about feed market conditions. The workshops were the Value Chain Workshop (France, 2018), the Markets Workshop (the Netherlands, 2018) and the Green Protein Cluster (the Netherlands, 2018). At workshops value chain actors and representatives of government have been asked to provide their views on fodder- and grain-legumes in the feed value chains.

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Appendix II: Background to the TRUE-Project

TRUE Project Executive Summary

TRUE's perspective is that the scientific knowledge, capacities and societal desire for legume supported systems exist, but that practical co-innovation to realise transition paths have yet to be achieved. TRUE presents 9 Work Packages (WPs), supported by a *Intercontinental Scientific Advisory Board*. Collectively, these elements present a strategic and gender balanced work-plan through which the role of legumes in determining '*three pillars of sustainability*' – '*environment*', '*economics*' and '*society*' - may be best resolved.

TRUE realises a genuine multi-actor approach, the basis for which are three *Regional Clusters* managed by WP1 ('*Knowledge Exchange and Communication',* University of Hohenheim, Germany), that span the main pedo-climatic regions of Europe, designated here as: *Continental*, *Mediterranean* and *Atlantic,* and facilitate the alignment of stakeholders' knowledge across a suite of 24 Case Studies. The Case Studies are managed by partners within WPs 2-4 comprising '*Case Studies'* (incorporating the project database and *Data Management Plan*), '*Nutrition and Product Development'*, and '*Markets and Consumers'.* These are led by the Agricultural University of Athens (Greece), Universidade Catolica Portuguesa (Portugal) and the Institute for Food Studies & Agro Industrial Development (Denmark), respectively. This combination of reflective dialogue (WP1), and novel legume-based approaches (WP2-4) will supplies hitherto unparalleled datasets for the '*sustainability WPs*', WPs 5-7 for '*Environment*', '*Economics'* and '*Policy and Governance'.* These are led by greenhouse gas specialists at Trinity College Dublin (Ireland; in close partnership with Life Cycle Analysis specialists at Bangor University, UK), Scotland's Rural College (in close partnership with University of Hohenheim), and the Environmental and Social Science Research Group (Hungary), in association with Coventry University, UK), respectively. These *Pillar WPs* use progressive statistical, mathematical and policy modelling approaches to characterise current legume supported systems and identify those management strategies which may achieve sustainable states. *A key feature* is that TRUE will identify key *Sustainable Development Indicators* (SDIs) for legume-supported systems, and thresholds (or goals) to which each SDI should aim. Data from the *foundation WPs* (1-4), to and between the *Pillar WPs* (5-7), will be resolved by WP8, '*Transition Design',* using machine-learning approaches (*e.g. Knowledge Discovery in Databases*), allied with *DEX* (*Decision Expert*) methodology to enable the mapping of existing knowledge and experiences. Co-ordination is managed by a team of highly experienced senior staff and project managers based in The Agroecology Group, a Sub-group of Ecological Sciences within The James Hutton Institute.

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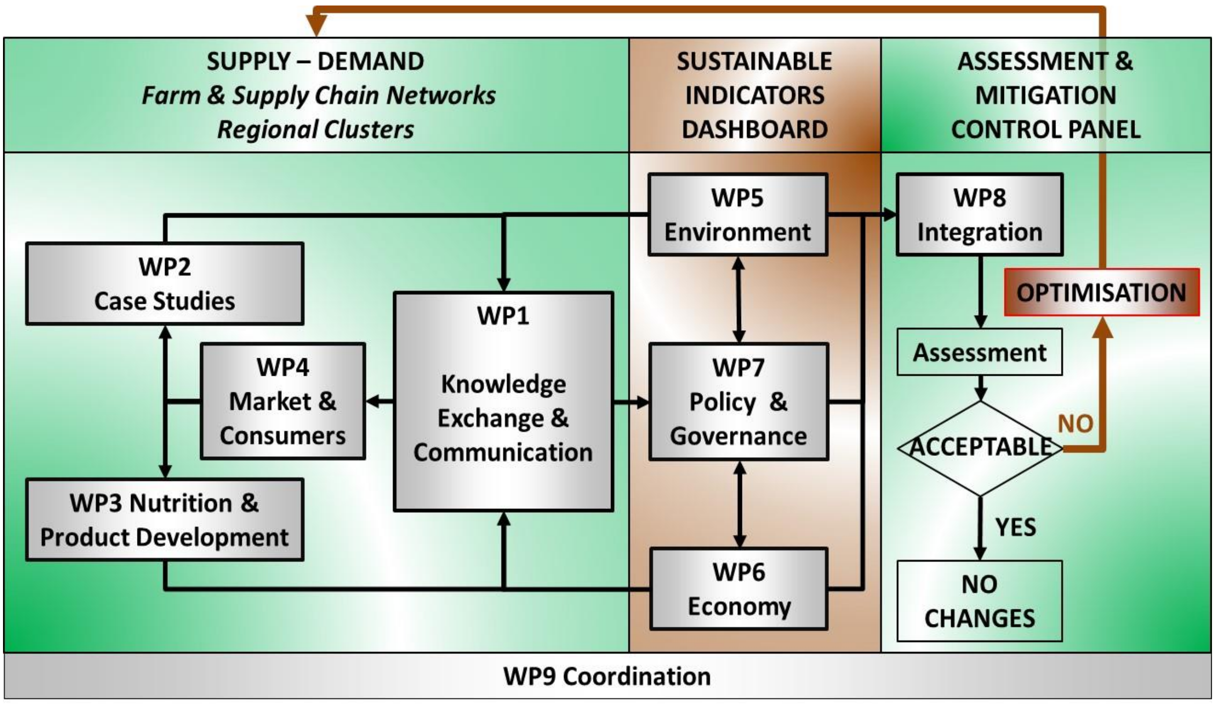
Work Package Structure

Flow of information and knowledge in TRUE, from definition of the 24 case studies (left), quantification of sustainability (centre) and synthesis and decision support (right).

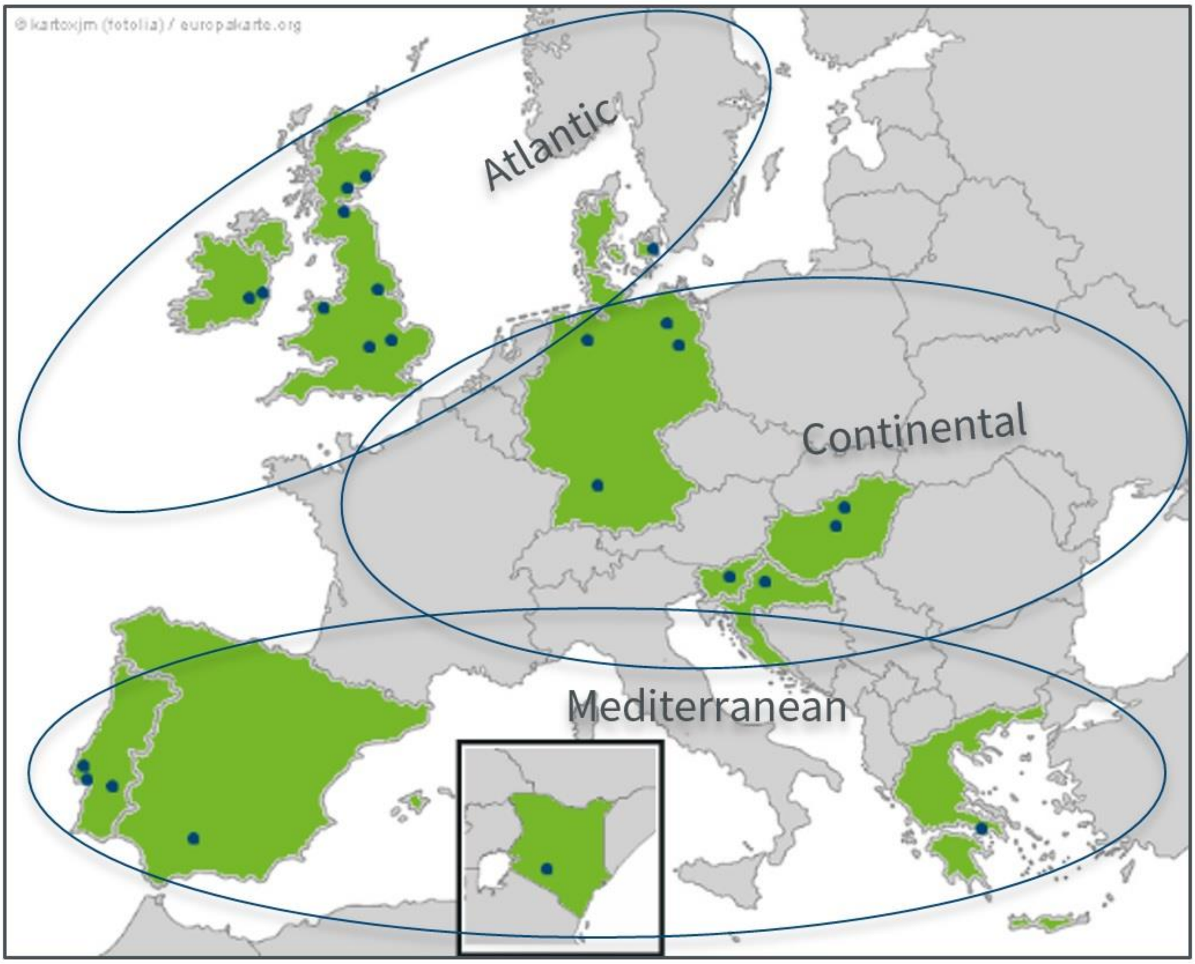


Project Partners

Nº.	Participant organisation name (and acronym)	Country	Organisation Type
1 (C*)	The James Hutton Institute (JHI)	UK	RTO
2	Coventry University (CU)	UK	University
3	Stockbridge Technology Centre (STC)	UK	SME
4	Scotland’s Rural College (SRUC)	UK	HEI
5	Kenya Forestry Research Institute (KEFRI)	Kenya	RTO
6	Universidade Catolica Portuguesa (UCP)	Portugal	University
7	Universität Hohenheim (UHOH)	Germany	University
8	Agricultural University of Athens (AUA)	Greece	University
9	IFAU APS (IFAU)	Denmark	SME
10	Regionalna Razvojna Agencija Medimurje (REDEA)	Croatia	Development Agency
11	Bangor University (BU)	UK	University
12	Trinity College Dublin (TCD)	Ireland	University
13	Processors and Growers Research Organisation (PGRO)	UK	SME
14	Institut Jozef Stefan (JSI)	Slovenia	HEI
15	IGV Institut Für Getreideverarbeitung Gmbh (IGV)	Germany	Commercial SME
16	ESSRG Kft (ESSRG)	Hungary	SME
17	Agri Kulti Kft (AK)	Hungary	SME
18	Alfred-Wegener-Institut (AWI)	Germany	RTO
19	Slow Food Deutschland e.V. (SF)	Germany	Social Enterprise
20	Arbikie Distilling Ltd (ADL)	UK	SME
21	Agriculture And Food Development Authority (TEAG)	Ireland	RTO
22	Sociedade Agrícola do Freixo do Meio, Lda (FDM)	Portugal	SME
23	Eurest -Sociedade Europeia De Restaurantes Lda (EUR)	Portugal	Commercial Enterprise
24	Solintagro SL (SOL)	Spain	SME
25	Public Institution for Development of Međimurje REDEA (PIRED)	Croatia	Development Agency

*Coordinating institution

Legume Innovation Networks



Knowledge Exchange and Communication (WP1) events include three TRUE European Legume Innovation Networks (ELINs) and these engage multi-stakeholders in a series of focused workshops. The ELINs span three major biogeographical regions of Europe, illustrated above within the ellipsoids for Continental, Mediterranean and Atlantic zones.

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