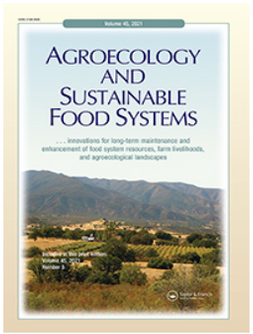

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Integrated policy analysis to identify transformation paths to more sustainable legume-based food and feed value-chains in Europe

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ABSTRACT

The food- and feed-value systems in the European Union are not protein self-sufficient. Despite their potential to improve the well-being of arable cropping systems, sufficient production of high-protein legume grains in Europe has not been achieved due to multiple barriers. The reasons are multiple and span economic, agronomic, research, and extension services, as well as aspects of culture and traditional dietary habits. Given the well-documented advantages of legume-supported production systems and diets, that include ecosystem and health provisions, acknowledging and promoting legumes as cornerstone species for more sustainable agri-food systems is a necessary and logical step. This paper provides an integrated analysis of case studies and current policies that shape the production and consumption of legumes in Europe. This study identified three key pathways, which can be integrated into sustainable farming systems to support current and future food security challenges via the use of legumes and legume-based products. At each pathway, we identified several enablers that support the sustainability transformation of legume production and consumption in Europe.

KEYWORDS

Legumes; food- and feed-value systems; food policies; protein; environmental impact

Introduction

Legumes deliver multiple agronomic and environmental benefits which can enhance the sustainability of diverse cropping systems and across Europe's varied pedoclimates. Legume crops can increase the yield of subsequent crops *via* their capacity to fix atmospheric di-nitrogen gas (N_2) into biologically useful nitrogen (N) forms, delivered by a symbiotic partnership with soil bacteria which may be termed collectively as 'rhizobia'. Besides, their post-harvest residues left in-field can help increase soil carbon and N content and soil functional properties (Jensen et al. 2012). It is estimated that global N fixation by legumes is between 33 and 46 mt y^{-1} for above- and below-ground N, respectively (Herridge, Peoples, and

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Boddey 2008), which can reduce chemical fertilizer needs. For instance, in France, it is estimated that legumes could decrease 7% of chemical fertilizer emissions, with yearly savings of € 77 million (Dequiedt and Moran 2015). Furthermore, well-managed grain legume crops require fewer inputs (mineral N fertilizers, pesticides) than other crops such as cereals and nonlegume oleaginous species. The potential economic value of legume-based crop rotations has been reported by many authors, especially within organic cropping systems (Köpke and Nemecek 2010). Similarly, studies focussed on conservation regimes where soil-disturbance is minimized (no- or minimum-tillage), and soil-cover is maximized (cover crops and post-harvest residues left in-field) (Robson et al. 2002; Schilizzi and Kingwell 1999). One of the economic advantages of including legumes in a crop-rotation is their capacity to help increase the range of crop species which are cultivated. Such diversity reduces otherwise dominant disease burdens and the necessity for external inputs of pesticide (including herbicide) applications, and their secondary effects.

Grain legumes present an alternative to meat and dairy protein intake as they constitute a vital source of plant protein and other essential macro- and micro-nutrients, plus important non-nutritionals, and are therefore crucial elements of a balanced diet low in saturated fat and high in fiber (Zander et al. 2016). For legumes, improvements on several health biomarkers can be found when daily amounts of 150 g (minimum-maximum: 54–360 g/day; cooked) are attained (Ferreira et al. 2020). Changes in consumers' choices toward a plant-based diet have recently been brought forth as one of the critical solutions to the globally rising demand for meat, dairy products and their associated externalities (Alleweldt et al. 2013; Springmann et al. 2016; Van Dooren et al. 2014; Westhoek et al. 2014). The potential of dietary changes on greenhouse gas emissions, land use, and the agricultural system has been the subject of many recent studies (Gustafson et al. 2016; Haddad et al. 2016; Mason and Lang 2017; Van Dooren et al. 2014). Clark et al. (2019) have recently shown that foods associated with improved health have amongst the lowest environmental impacts, and legumes are listed amongst this food category (Afshin et al. 2014). These studies concluded that a dietary transition toward higher consumption of healthier foods would generally improve environmental sustainability (*i.e.* the '*Planetary Diet*') (Willett et al. 2019) besides leading to better health. Triggering dietary change would require increasing production of plant-based protein, implying radical shifts in production areas, with necessary land-use costs, and also a transfer of protein sources for human consumption (Westhoek et al. 2014). Therefore, the transition toward sustainable diets necessarily entails a transformation of the global agri-food systems.

Despite the health, economic and environmental benefits, legumes are rarely placed at the center of policy debates on global food and nutrition security (Agrawal 2016). Previous EU-funded projects such as Legumes Futures[1] (Helming et al. 2014) Legvalue[2] (Magrini et al. 2019) and Legato[3] (Thompson

et al. 2014) demonstrated that there is a lack of quantification and understanding of long-term benefits *versus* the short-term and often monetized gain of current dominant policies. In this paper, we generated an analytical framework to determine how policies and governance solutions may enable or limit legume production in Europe. We provide an analysis of the current policies that shape the production and consumption of legume grains through a review of the current literature and in-depth policy analysis based on case studies carried out in 7 European countries. We conclude by delineating policy prospects for a transition to legume-based food and feed value systems in Europe.

Methodology

The analytical framework developed in this study was designed to determine how actual policies and governance solutions enable or limit legume production, and is based on two approaches: 1) literature review and document analysis, and 2) analysis of case-studies. The literature review and document analysis were used to assess how current EU-level policies influence the production and consumption of legumes in Europe. In contrast, the analysis of case studies was used to contextualize the results of the literature review described above. The literature search comprised terms such as 'legum*' or 'pulses' and 'policy analysis' and 'Europe' and papers published between 2019–2014 were selected, while papers published before 2014 were analyzed only if cross-referenced by several of the selected papers. Commonly used databases such as ScienceDirect, Web of Science, and Google Scholar were searched. Key policy documents such as the *European Protein Plan* (EC 2019), the *Green Public Procurement* (Directive 2014/24/EU) and the 7th *Environmental Action Plan* (Decision No 1386/2013/EU[4]), were also analyzed. Case studies regarding policies regulating legume production and consumption were collected by experts in Germany, Italy, Croatia, Denmark, Portugal, Hungary, and Scotland. The collection of data for the case studies was structured in an 8-step procedure, as described in Table 1. In each country, experts focussed on one focal issue, and relevant policy documents at the national level were identified and analyzed in detail. In addition to document analysis, 24 interviews were carried out with different stakeholders (including producers, processors, lobby groups or professional networks, extension service providers, and policymakers). The length of interviews – either carried out face-to-face or online – ranged between 30–90 minutes. Written notes were taken, focusing on the experiences and opinions of the interviewees on policies regulating legume production and consumption.

Stakeholder interviews were constructed on a common framework used in all case studies, and addressed the following key topics:

Table 1. Collection of data for the case study was structured in 8 steps and research questions. Sources of data and methods of research are described for each step.

Steps	Research Question	Sources	Method
1. Delineation of case study	Which policy/governance solution is the subject of your analysis?	Expert knowledge; published literature	Expert justification
2. Unfold key challenges	Which policy challenges are targeted by the policy/governance solution of your case?	Literature review produced in this study	Expert justification
3. Identify and collect key documents	Which legal and strategic documents play a key role in your case study?	Laws, decrees, strategies, recommendations which have officially been published as part of the analyzed policy solution	Desk research
4. Preliminary document analysis	How do key legal and strategic policy documents frame the issue?		Desk research
5. Secondary data collection	Which scientific and public narratives are relevant in your case?	White and gray literature and media release	Desk research
6. Secondary data analysis	How can the policy process be characterized based on the scientific and public discourse?	Interviews with stakeholders	Interviews with stakeholders
7. Corroborate preliminary results	How do key stakeholders perceive and evaluate the policy solution?	Interviews with stakeholders	Interviews with stakeholders
8. Write the 'story'	How does policy enable or limit the production and consumption of pulses?	Material collected for the case study as described above	Data analysis, policy formulation

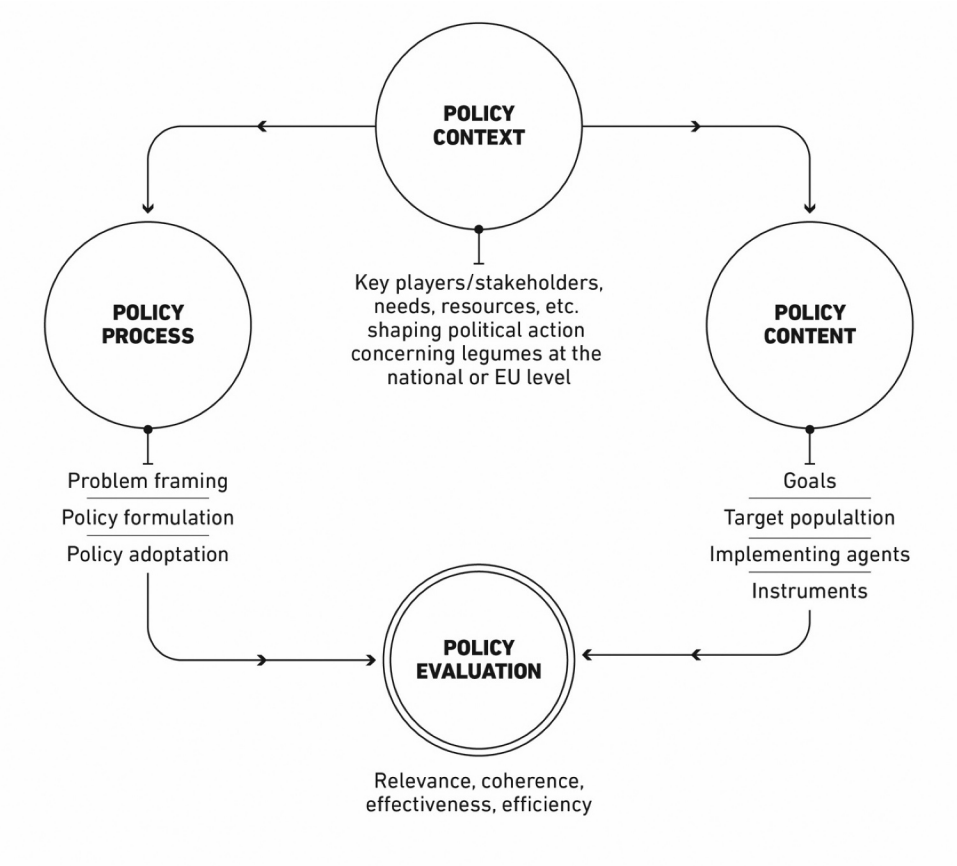

Figure 1. The analytical framework of the policy analysis based on case studies. The policy process is based on Jokinen et al. (2018) and the policy content is based on Vogel and Henstra (2015).

(I) What are the practical policy challenges to increase legume production and consumption in Europe?
(II) What policy approaches already exist in support of legume production and consumption?
(III) What is the most necessary policy change at the European and county levels?
(IV) How can different stakeholders' interests be embedded in the formulation of a policy framework in support of legume production and consumption?

Data were analyzed according to core analytical aspects, identified *a priori* (Figure 1). Interpretive policy analysis (Yanow 2006) was applied to support policy formulation based on three key characteristics: the context, the process, and the content of the policy. Each of these characteristics can be shaped by

major actors as well as the phases of the policy process or the goals and instruments of the policy (Jokinen et al. 2018; Vogel and Henstra 2015).

Results and discussion

Barriers to legume-based food- and feed-systems

Results of the literature review and document analysis used to assess how current EU-level policies influence the production and consumption of legumes in Europe show that many barriers exist. On average, protein crops are now grown on only 1.8% of arable land in the EU, compared with 4.7% in 1961. This decline is the result of several social, economic, and policy factors. The shift in the cultivation of common bean (*Phaseolus vulgaris* L.), a previously widely cultivated grain legume for food, to soybean (*Glycine max* L.) and protein feed crops such as fava bean (*Vicia faba* L.) and pea (*Pisum sativum* L.) was highlighted in the 1970s due to the introduction of policies and subsidies to support more intensive food production systems. This shift was also achieved using cereals, which offered higher and more stable yields and that was afforded as a function of specific more-genetically fixed (highly inbred) and improved cereal genotypes, and high levels of inputs.

Productivity gains of legumes are lower than those observed in major cereals due to legumes' high-yield variability and high variability of economic returns (i.e. gross margins: LMC International 2009), as well as the lack of public and private upstream investment: in breeding, technological developments and specialist advice from independent extension services for legumes, which should be locally adapted and cultivable in European soils and environments. The performance of legume crops is, by contrast to cereals, more regionally specific. Biological N fixation requires energy, provided in the form of photosynthate (carbohydrate or sugar) by the legume, and this is thought to increase the gap between realized-yields and yield-potential. However, these production risks are often context-dependent, as legumes are generally grown on less fertile soils for feed (Döring 2015; Reckling et al. 2015). Moreover, legumes are often poorly managed since they are realized as crops to produce a 'disease break' as opposed to a 'cash crop' of equal or higher value than other nonlegume crops in the cropping-sequence.

The potential for grain legumes for food is substantial within the EU (Hallström and Börjesson 2012). The market for plant-based diets (where legumes play a significant role) has been growing in the last decade (Logatcheva and van Galen 2015). Yet, the EU is a net importer of field pea and faba bean consumed by humans, and the largely increased demand for meat drives the imports of protein for animal feed. The European Union is highly dependent on non-taxable soybean imports for feed (about 70% of EU requirements for high-protein crop commodity is imported), and soybean is currently imported without duties (Bindraban and Rabbinge 2011). Prices of

protein crops have recently increased faster than those of cereals (mostly wheat); imported soya became more costly as has the price of nitrogenous fertilizers. It is, however, evident that despite the multiple agro-environmental benefits and ecosystem services, and the rising market incentives, legume production and consumption in Europe have not yet caught up with these trends. The reasons for the low production and consumption of legumes in Europe are multiple. Table 2 summarizes the current barriers and policy challenges that could help reverse this trend.

On the production side, simplification and specialization trends, especially for cereals and oil crops (Zander et al. 2016) explain part of this abandonment. Other reasons include: a) technological 'lock-ins' within the production system of legumes (Magrini et al. 2016); b) the low degree of understanding and appreciation of non-marketed products and services of legumes by farmers; c) low impact or absence of agri-environmental regulations and public or private payments that address the negative externalities produced by market failure of crop specialization; d) the comparable lower yields and yield instability of legumes when compared to other major nonlegume crops; and e) reduced access to sufficient and publicly-funded independent agricultural extension or advisory services skilled in legume-based crop system management.

For several reasons, as explained by the theory of socio-ecological coevolution (Kallis and Norgaard 2010), legumes are alternative crops that have received less investment and learning than other crops (i.e., cereals). During the green revolution, cereals were the target of most research and development efforts which have resulted in a rapid increase of yields on monocultures and economy of scales, creation of genetically diverse varieties with high yields, and "increasing return to adoption" (the larger the number of users, the greater the value for each of them, Magrini et al. 2016). In turn, as production systems for cereals was adopted across the world, the more their production costs decreased – and at the expense of alternatives (i.e., legumes). Zander et al. (2016) called this process the economic effect of crop specialization, and Annicchiarico (2017) defines it as "path dependencies". Consequently, farmers lack appreciation and understanding of legumes' farm-level benefits. For example, underestimation of the provision of N to subsequent crops (hence, saving of N fertilizer for the post-crop) and the low fertilizer-to-product price does not stimulate farmers to implement intercropping, mixed cropping or crop rotations with legumes (Preissel et al. 2015). Extension services backed by public research programs and associated knowledge exchange programs could improve the understanding of the economic, agronomic and environmental benefits of legume production. The success of legume production in Canada and Australia is due to the massive support of extensive public agronomic R&D, and investment in technology of breeding, processing, and distribution. In some cases, trade agreements support imports of commodities (such as soybean as a protein

Table 2. Current barriers and policy challenges to the increase of legume production and consumption in Europe.

Barriers and policy challenges	Description	Case study - country	Level	Citation
CAP/trade policies	- CAP's intense focus on production without sufficient support along the value-chain, no direct focus on legumes, and agroecological services undervalued by producers and society - Compartmentalization, lack of coherence and polarization of policies at EU level	Italy, Germany	National and EU level policy	Bues et al. 2013, IPES-Food 2017 and 2019; Sander et al. 2012
N fertilizer policies	- Overuse/inefficient use of synthetic nitrogen, managing risk of leaching	Germany and Scotland	National and EU level policy	Musacchio et al. 2020; Lu et al. 2015; EC 2019; Stokstad 2019
R&D (breeding, processing technology)	- Challenges of breeding programmes (lack of state-financed programmes or private institutions, few investments in product development, lack of improvement and testing of local varieties)	Croatia, Scotland, Germany	National-level policy	Annachiarico 2017; Calles et al. 2019; Häusling 2011; Helming et al. 2014; Meynard et al. 2018
Extension services/ Profitability to farmers	- Difficulties of bridging regional supply and demand (decoupling from import in the feed sector, labeling food as regional, creating short food supply chains in the food sector) - Profitability is questioned by farmers (pest control, variable yields, not competitive with soybean, difficult to internalize external costs) as they are left without management tools and proper extension services - Proximity to processing facilities and trading companies	Scotland, Germany, Croatia, Italy	National-level policy	Bues et al. 2013; Magrini et al. 2016, Zander et al. 2016; Preissel et al. 2015
Consumers' preferences/ Public procurements/ dietary guidelines	- Public perception of pulses – not attractive enough - Lack of knowledge regarding the nutritional and health value of legume by consumers - Improved availability as convenience- or snack-foods, and access to information on cooking in easy-to-follow recipes	Denmark, Portugal and Hungary	Voluntary and National level policy	Oré Barrios, Mäurer, and Lippert 2020. Mason and Lang 2017; Ferreira et al. 2020; Lemken et al. 2017; Willet et al. 2019

source) at the expense of supporting public research on such crops in the importing countries (i.e., Kennedy round and Blair House agreements between Europe and the USA; Annicchiarico 2017; Bues et al. 2013).

The EU has committed to reduce GHG emissions by at least 40% until 2030 and to become carbon neutral by 2050. The agriculture sector will be part of this effort, through the '*Effort Sharing Regulation*' and the '*Land Use Land Use Change and Forestry Regulation*' (LULUCF). These regulations are part of the '*EU Climate and Energy package 2030'* (EC 2020).[5] There is an agreement in the EU research and policy communities regarding the overall utility of reintroducing protein crops, mainly legumes and specialized crops, to improve the sustainability of European agri-food systems (c.f. *EU Agricultural Outlook for Markets and Income* 2019–2030 (EC 2016), and the *Farm to Fork strategy of the European Green Deal*, EC 2019). Also, at the EU level, a transition from an agrochemical-dependent to an agroecological-dependent paradigm has been frequently suggested and formally recognized in national agricultural policies (e.g., France (Guitton 2014) and Germany (Sanders, Offermann, and Nieberg 2012)) (Calles et al. 2019; Häusling 2011; Helming et al. 2014; Meynard et al. 2018).

Policies in support of homegrown legumes (EC 2019) are present both at the EU level through the Common Agricultural Policy (CAP) and at member states level with support to diversification, agroecology (France) and pulses in general (Germany). However, these policies have been only a patchwork of separate components which did not fully engage all the stakeholders and beneficiaries and did not prompt a paradigm shift which tackles the entirety of the value-chain (Mason and Lang 2017). Potentially significant causal factors, which have not been tested due to poor data availability that may be positively linked to legume production, include proximity to processing facilities and trading companies and access to extension services, regional networks and training programs (Oré Barrios, Mäurer, and Lippert 2020). In order to support this transition, several policies should be reviewed and aligned for better inclusion of legumes in the agri-food systems (see discussion and Figure 2 below).

Context-specific challenges and opportunities

The case studies were conducted in seven European countries (Croatia, Denmark, Germany, Hungary, Italy, Portugal, and Scotland), and focused on different upstream and downstream components of the value chain. Some examined the role of different types of stakeholders, targeted policies, and societal context from the demand side (legume consumption, *e.g.* Denmark, Hungary, Portugal, and Scotland), while others had a broader scope in terms of the value-chain, and provided a more detailed understanding of the supply side (legume production, *e.g.* Croatia, Italy, Germany). Summary results are presented in Table 3. In this Table we focus on two questions: 1) what policy approaches do already exist in

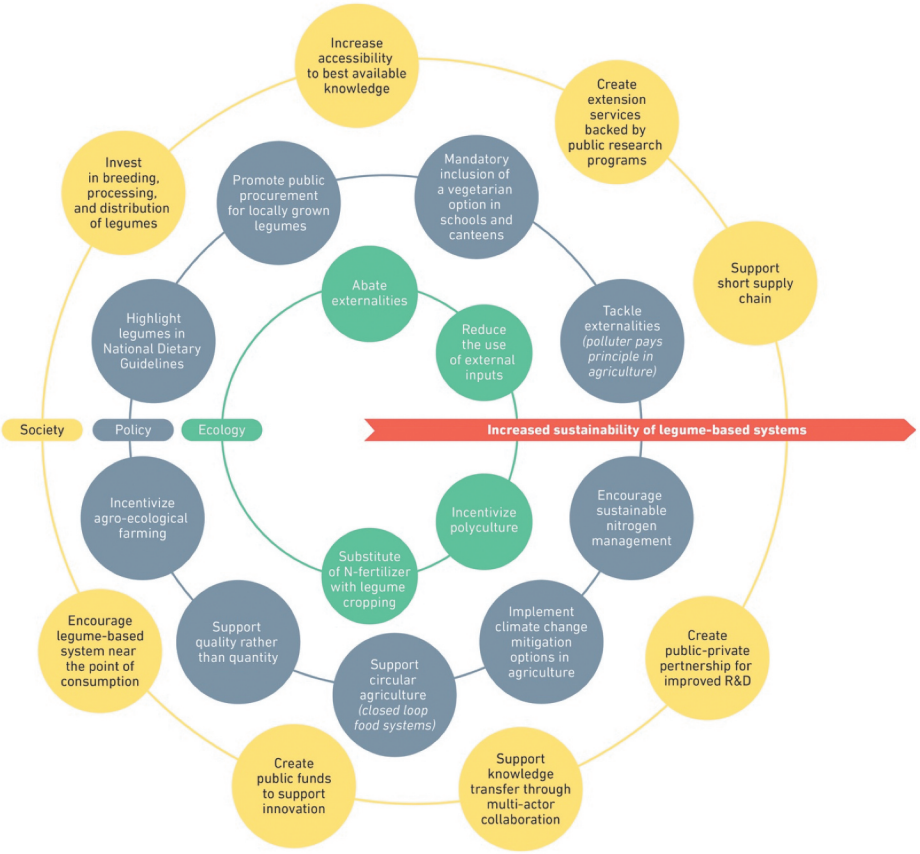

Figure 2. Pathways and enablers for increased sustainability of legume-based systems.

each country to support legume production and consumption, and 2) what are the policy challenges to increase legume production?

Legume production

The in-depth analysis shows few currently available relevant policies to support legume production. At the European level, the CAP is the main policy to support legume production within the greening payment and the EFA (Ecological Focus Area) of Pillar I. A description of the existing policy approaches, key stakeholders and policy challenges to increase legume production and consumption is presented below and summarized in Table 3.

Currently, as reported by Bues et al. (2013), legume production is supported by voluntary support direct measures within 'Greening Measures' (crop diversification) and within agri-environment schemes (i.e., EFAs in Pillar 1 of the CAP). However, member states choose to apply these measures voluntarily,

Table 3. Summary description of the existing policy approaches and challenges to increase legume production and consumption in the studied countries in the EU.

Relevant Policy field	Country	What policy approaches already exists?	What are the policy challenges to increase legume production?
Agriculture	Croatia	- No targeted policies for incentivizing legume production or to improve the legume-knowledge base of farmers through the agriculture advisory. - Farm Advisory service "*Strategic Plan of Work for Period 2018–2020"* N.14 *professional supervision of integrated farming*, encourages legumes production at the level of national legislation. Famers who want to be part of the register of integrated production must include legumes in crop rotation. - CAP Greening Measures.	- Farms engaged in crop production, use legumes as one component of crop rotation and as a 'green nitrogen fertilizer' source. It is important to target the whole supply-chain, since this approach recognizes the importance of the supply (production) and demand (consumers/end-users) elements which are necessary to collectively increase the uptake of homegrown legumes
CAP and Protein strategy	Italy	- CAP Greening Measures (coupled direct payments for oilseed that include soybean as a rotation crop). - Crop diversification is one of the requirements for eligibility for the greening payment in the CAP Pillar 1.	- Research and extension service capacities are necessary to drive improvements *via* modern cultivation technologies and improved varieties. The government-funded research institutions struggle to provide this type of service. New sustainable business models based on public-private partnership need to become more widely used.
CAP and Protein strategy	Germany	- Protein Crop Strategy "Diverse crops on Arable Land" under the CAP pillar II which is part of agro-environmental and climate protection measures. - Financial incentives are provided to farmers that grow legumes (large grain legumes and legume mixes) in combination with the EFA or independently from EFA and under organic or conventional farming.	- Sustained legume production will continue after incentives terminate, only if there are market opportunities that ensure steady demand and product valorization.
Public Food Procurement	Denmark	- "Organic Eating Label" (increase the use of organic legumes both for food and feed). - EU Green Public Procurement initiative.	- Further research and testing activities involving food service actors are needed to clarify how "sustainability" can be operationalized or implemented to ensure legumes and legume-based products are fully recognized and acknowledged in the food supply chains and foodservice market.
Public Food Procurement	Hungary	– 1/2011 Normative Instructions and Recommendation by the Chief Medical Officer of State - 37/2014 Decree of the Ministry of Human Resources has been launched to regulate public food provision from a nutritional point of view (the Decree came into force in 2015). - 36/2016 Amending Regulation or the 37/2014 Decree of the Ministry of Human Resources on Public Food Procurement.	- Legumes remain to be considered only as vegetables and are not accounted as commodities of high nutritional value in their own right and are acknowledged as such in menus. - Private and social initiatives are important to increase the acceptance of legal reforms and create trust between the parties. - Bringing healthy food at the forefront of public debate can also make room for promoting legumes.

(*Continued*)

Table 3. (Continued).

Relevant Policy field	Country	What policy approaches already exists?	What are the policy challenges to increase legume production?
Public Food Procurement	Portugal	- "Circular 3/2013: Orientações sobre mental e refeitórios escolares" (Guidelines on menus and school cafeterias) and new update to this document (made public in July 2018). - Lei 11/2017: Estabelece a obrigatoriedade de existência de opção vegetariana nas ementas das cantinas e refeitórios públicos (Establishes the mandatory existence of a vegetarian option in the menus of canteens and public cafeterias).	- The main operational difficulties experienced when implementing such policies are not related to the nutritional qualities of the legumes, but rather the high organoleptic qualities of the recipes cannot be replicated due to the lack of legume cooking skills among cooks and kitchen helpers. - A challenge is ensuring that consumers are fully informed of the nutritional qualities of the legume-based alternatives, comparing with the standard options.
Agriculture	Scotland	- The "good food nation" Bill has been adopted by the Scottish government and its implementation includes an objective that every Scottish city must establish a "good food policy" that includes promotion of "food and drink education" and "sustainable production procurement".	- The main requirement for increasing legume inclusion is demand for new home-growth or provenanced (and ethically produced) legume-based products in the food, feed, and processing industries. Any planned programme of legume expansion should take into consideration (and resolve) the consequences of the reduction in the barley area. A further limitation of using legumes in aquaculture as animal feed is the current lack of processing facilities. - Government intervention through policy legislation, infrastructure and market development is needed to enable farm-level economic initiatives and innovations that include legumes, and the development of legume supported value (or supply) chains.

without having a long-term goal, and so impact on system sustainability attributes remain unchecked. Bues et al. (2013) point out that the crop diversification measures are not sufficiently stringent to facilitate diversified non-cereal cropping systems because there are no specific indications on which crop types (and associated management measures) are needed to be co-introduced to reach biodiversity- and/or environmental-protection goals. Hence, to more-effectively introduce legumes within the greening measures, it would be necessary to specify crop plant families, genera and preferred management options. Furthermore, within the EFA, legumes may not provide the same level of biodiversity provision as accommodated by other EFA options, such as hedgerows, buffer strips, afforested areas, etc. Promoting biodiversity per se is insufficient to bring more legumes to farmer's fields.

Regional policies to support legume cultivation exist in only a small number of EU member states (see Tables 2 and 3 in Zander et al. 2016), and these are relevant only for specific regions within each state. For example, in our case studies, Germany implemented the Protein Crop Strategy "*Diverse crops on Arable Land*" which is part of agro-environmental and climate protection measures under the CAP Pillar II. The Farm Advisory Service in Croatia has implemented the "*Strategic Plan of Work for Period 2018–2020*" N.14 *professional supervision of integrated farming*" which encourages legumes production at the level of national legislation. The central policy for which farmers receive economic incentives to grow soybean or legumes, in general, is within the remits of the EU CAP.

The policy challenges to increase legume production are related to the creation of government intervention through policy legislation, infrastructure and market development to enable farm-level economic initiatives and innovations that include legumes, and the development of legume supported value (or supply) chains. For example, in the German case study, farmers' willingness to grow legumes (non-GMO soybean) was connected to the provision of advice from extension services, and farmer-to-farmer knowledge transfer as well as the creation of a partnership with a tofu producing company that provided farmers with steady demand and product valorization. Similarly, in Italy, the demand for non-GMO soybean by the dairy industry (Consortium of Parmigiano Reggiano) provides a steady demand, and the presence of the private industry covers the production side from seed procurement to harvest by providing extension services and varieties that can withstand climate change and pest attacks.

Legume consumption

The case study from Denmark shows that the creation of a label for organic food ("*Organic Eating Label*") increased the use of organic legumes both for food and feed. Indeed, leguminous crops are part of the rotation scheme in organic farming. By introducing the requirement to include organically grown

legumes in public procurement schemes, Denmark indirectly positively influenced the production and consumption of legumes. Similarly, in Portugal and Hungary, the implementation of laws in favor of green public procurement which emphasizes healthy foods and vegetarian options can result in an increase in legume consumption in canteens and other public food distribution areas. However, in Hungary, legumes remain to be considered a vegetable instead of being accounted as commodities of high nutritional value in their own right, and they are acknowledged as such in menus. In Portugal, one major challenge for the expansion of legume consumption is the absence of cooking skills by the publicly employed cooks and the lack of knowledge regarding the nutritional and health value of legume by consumers. In Scotland, in response to policy (in)action, private sector-led initiatives emerged recently with a strong future potential of increasing the share of legumes in production and consumption. These initiatives include: 1) using legumes in animal feed, especially aquaculture; 2) developing new products based on homegrown grain legumes; 3) using new legume varieties and innovative practices; and 4) promoting public health and dietary change. Even though there could be opportunities for the creation of the legume market in aquaculture, the main limitation of using legumes in aquaculture as animal feed is the current lack of processing facilities.

From a nutritional and economic point of view, legumes represent an affordable, nutritious alternative to meat and dairy-based products as they provide high protein (17–30%), essential minerals, resistant starch and fiber content (Boye, Zare, and Pletch 2010), and as a dry product, they have a very long shelf life. However, the consumption of legumes as food is strongly tied to local resources and cultural heritage. The impact of homegrown legumes for local consumption (and nutritional benefit) is still small-scale.

Pathways to sustainable legume food- and feed-value chains

The policy analysis and in-depth case studies at the EU and national level identified three major pathways (levels) for increased sustainable legume-based systems. The three pathways involve: 1) Co-benefits (ecology); 2) Implemetation (policy); and 3) Actors (society). At each pathway, we identified several enablers that support the sustainability transformation of legume production and consumption in Europe (Figure 2). These pathways are explained in detail in the following paragraphs.

Capitalize on ecological enablers to improve legume-based agri-food systems

Policies that support the reduction of mineral (synthetic) N fertilizer can indirectly incentivize the cultivation of legumes, and if properly managed, help maintain soil and water qualities, and reduce GHG emissions. For example, the EU Nitrates Directive (91/676/EEC) (Musacchio et al. 2020),

which is closely aligned with the EU Water Framework Directive (2000, 60/EC), limits the amount of nitrates from agricultural sources to protect water quality, by limiting practices such as crop fertilizer rates, animal-stocking rates, and animal access to waterways. However, these directives are implemented differentially nationally, and even regionally, and iterations could recommend substituting highly N-fertilized crops by legumes (grain or forage types). The Netherlands offers one example of national policies targeted at the reduction of nitrogenous emissions, whereby a 'permit system' was introduced in 2015. Permits are issued by regional governments for construction projects whose nitrogenous emissions are offset by reductions made in other sectors such as farming. Dutch farms contain four times more animal biomass per hectare than the EU average, and almost half of the atmospheric N pollution that falls in the country is caused by agriculture. Experts created the concept of 'circular agriculture': animal stocking density must match the capacity for on-farm co-product recycling – such as via manure application as a fertilizer, and that feed self-sufficiency is prioritized through grazing locally cultivated legume grains and/or legume-grass swards. If adopted, this approach would mean that 50% fewer animals would be nurtured. It is expected that the EU courts might impose similar sanctions on other European Community member countries in the future (Stokstad 2019). In the interim, practices have already been implemented in The Netherlands, which improve agricultural N use efficiency. They include soil injection-systems for the application of liquid manure and the use of air-purifiers on pig and poultry containment-facilities that have reduced ammonia emissions by 60% since the 1980s (though they have risen slightly since 2014 due to the expansion of dairy operations). For permanent grazed pastures, implementation mechanisms can extend to more extensive (as opposed to intensive) pasture (grazing) management. For mixed-farming (where livestock and crop production are integrated into the same production unit), longer-term grass-based lays within crop rotations may be demanded, the use of forage legumes serving as an essential source of protein for livestock feed. The mixed-farming approach is typical of agroecological principled farming, where the combination of legumes and livestock (manure) serve as the main sources on-farm N-fertility provision. On the other hand, intensive animal husbandry, in mixed or specialized (livestock only) units, can be a major contributor to nitrate pollution. Animal feed demands in such systems depend upon the import of protein from outside the EU. Currently, conventional, or intensive, production systems are characterized by being specialized, monocultural, highly input-dependent with several negative impacts within and beyond the production environment itself. Such approaches are described as "productionist", and attempt to maximize yields, and so profitability, in the short-term. Additionally, the positive or negative environmental (and crop performance) impacts of management are not (yet) accounted for in resultant commodity

prices (Preissel et al. 2015). Conventional farming, and the downstream reinforcing agri-food chains, must pay compensation for any adverse environmental- and human health impacts. In this respect, it seems reasonable that specific policies are implemented to tackle externalities, such as via the '*polluter pays principle*' (Cordato 2001), and CAP and trade policies which encourage sustainable N management – as exemplified by the launch of the Food and Agriculture Organization of the United Nations, '*Global Campaign on Sustainable Nitrogen Management*' (Lu et al. 2015). An increase in the cost of carbon emissions by taxing greenhouse gas (GHG) emissions at a relatively high rate would make N fertilizer more expensive, and thus legumes more attractive. The '*EU Agricultural Outlook – Prospect for the EU agricultural markets and income 2016–2026'* (EC 2016) mentions legumes only linked to climate contexts as a mitigation policy option by which the high GHG costs of the EU agricultural sector may be offset.

Create a supportive and coherent policy environment

If the potential human- and environmental-benefits of legumes are to be realized in Europe, then policy objectives must be more effectively implemented to ensure as much as possible that the legume grains consumed as feed and food in Europe encourage legume-based cropping systems near the point of consumption, incentivizing local producers and processors to include legume in their cropping/businness systems. The cultivation of legumes in agroecological farming systems is a foundation of fertility provision, nutrient use efficiency, and soil quality preservation. However, most commodities that emerge from more sustainable, environmentally friendly farming approaches command a price premium which is most commonly afforded by the more affluent consumers. Thus, it is argued that higher uptake of products from sustainable farms should be incentivized. For example, within the CAP, a much more significant shift toward '*Rural Development*' (Pillar 2) is needed. Support for farmers should be linked to quality rather than quantity. Rather than support high input monoculture of large holdings, environmental protection and production of varied crops with high nutritional value should be favored and incentivized. As a specific example, the '*Agro-ecological Project'* in France and the '*BÖLN Scheme'* in Germany are two strategies that incentivize environmental protection to encourage more-sustainable food production. In France, the government worked on a new law made public on 13 October 2014, under the name of "*LOI No. 2014–1170 d'avenir pour l'agriculture, l'alimentation et la forêt*" (Law 2014–1170 of 13 October 2014, '*of the future for agriculture, food, and forestry*') (Guitton 2014). This law provides a rationale for the combination of economic, environmental and social performance through sustainable and highly productive agroecological practices.[6] In Germany, the BÖLN Scheme is funded by the Federal Ministry of Food and Agriculture, which provides financial support directly through the

CAP organic farming measure within the Rural Development Programmes. For the CAP period 2014–2020, the Ministry collectively has budgeted nearly 1.5 billion Euros for this support[7] (Sanders, Offermann, and Nieberg 2012). Such measures that support values and quality over quantity need to be integrated with investment into crop breeding and associated research and development programs.

Supporting legume production needs to be accompanied with measures to increase demand, because farmers will grow what there is a demand for. Higher uptake of legume-based foods is not merely a function of affordability or low-cost since it has been demonstrated that consumer demand is only changed significantly if factors other than price are considered. This can be accomplished, e.g. via the provision of targeted campaigns and better marketing of legumes' health- and environmental-benefits. Success in this regard is also a function of improved availability as convenience- or snack-foods, and access to information on cooking in easy-to-follow recipes (Lemken et al. 2017). From the consumer's standpoint, there are growing concerns regarding agrochemical and especially pesticide residues in food, and the nutritional value of highly processed food – and there is a general awareness of the adverse health effects of diets relying heavily on sugar, salt, and meat. Environmental and health concerns, as opposed to purely economic reasons, may influence consumers' choices, and these are often dependent on the consumers' "*food literacy*" level which is the combination of cultural history, education, the effectiveness of awareness campaigns and dietary guidelines. Inspiring examples of such educational campaigns come from Portugal, that places legumes in a dedicated section of the food wheel guide, from The French National Nutrition and Health Program's dietary guidelines (*French: Guides nutritions du Programme national nutrition santé* (PNNS)), that highlight three categories of action one of them being the increase of legume consumption, and the *Canadian Food Guide 2019* that emphasizes plant-based protein foods within the "protein foods" group by placing beans and lentils at the top of the list before nuts, other seeds and animal protein products (meat, poultry, fish, eggs and dairy foods).[8]

Engage actors along the value chain and from the broader society

The development of measures that support environmentally sensitive agri-food systems will depend on coordinated and complementary policy instruments rooted in a greater understanding of the agroecological processes governing the environmental, plus human and animal health benefits, of legumes. However, changes in the way we produce food must go together with changes in industrialized food (and feed) production and consumption.

Our policy analysis and case studies revealed a gap of importance and influence between actors along the value-chain. Policies at the consumption endpoint (*i.e.* procurement and nutrition-oriented policies) regulating bodies,

consumer groups (*e.g.* parents association in Portugal), professional organizations (*e.g.* association of dietetics in Hungary) and processors (*i.e.* catering companies) seem to be the most influential actors. At the same time, farmers stand somewhere in the middle, and actors at the lower end of the value-chain appear too or are treated as if they have much less influence. However, actors at the production endpoint of the value-chain (*e.g.* seed suppliers, crop breeders, agronomists) tend to have an equally important role as actors at the consumption endpoint, as they can have a significant impact on how the increased demand for raw materials or commodities can be met. Case studies analyzing policies that focus more at the production (and processing) segments of the value-chain indicate that processors and agronomists are equally important and influential players as farmers themselves and state regulators, while crop breeders, seed suppliers, or civil society are seen to play less relevant roles. However, in situations where existing and widely used breeds are not profitable enough, crop breeders and seed suppliers would be key actors, and support for research and innovation could contribute strongly to an increased volume of legume production. In some cases, multi-actor networks including farmers, advisors and breeders fill such gaps (*e.g.* in Germany) while in other situations one or a few market actors fill this niche and provide novel breeds as well as technical knowledge to farmers (*e.g.* in Italy).

Conclusions

Currently, the EU does not have a coherent single agri-food policy, and the ones relating to production or consumption are scattered within various sectoral policies (Agriculture, Environment, Health, Trade, Development, Cooperation, etc.) that are not mutually supportive and remain to be harmonized (IPES-Food 2019). EU agricultural policy goals are controversial since the desire to achieve sustainable food production and consumption does not often match agribusiness goals and socio-ecological needs. Policies that impact legume-based agri-food systems operate across many levels of governance shaped by international, EU, national and regional agreements. Our in-depth policy analysis indicates that fragmentation and inconsistency of existing policies create situations where actors of the value-chain face different incentives.

Policy analysts claimed that no single simple policy change could alter the current low status of legume cultivation and consumption in Europe (Topp et al. 2014). A suite of policy innovations are required to circumvent technological lock-ins, to promote legume consumption, increase their commercial competitiveness and move toward more sustainable food security. The Final Report of the European Innovation Partnership (EIP)-AGRI Focus Group on Protein Crops (Schreuder and de Visser 2014) contended that a step-by-step approach would be desirable to increase Europe's self-sufficiency of protein crop production. Policy integration – a mixed approach where agriculture and food policies are linked, and

inconsistencies are eliminated – would foster more comprehensive incentive systems where legumes are valued for the various benefits they offer to humans and the environment. This study emphasized the need to operate at various levels spanning ecology, policy and society thus enabling a shared understanding and co-innovation for legume-based farming systems, which comprises balanced participation of key stakeholders (Bentham et al. 2017). Given the current low level of legume production and consumption in Europe, whether and how far these needed changes will have a real positive impact is difficult to estimate. Still, the implementation of such changes is certainly the first step to increase the sustainability of food and farming systems.

Notes

1. www.legumefutures.eu accessed July 10, 2020.
2. www.legvalue.eu accessed July 10, 2020.
3. www.legato-fp7.eu accessed July 10, 2020.
4. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri = CELEX:32013D1386&from = EN accessed July 10, 2020.
5. The aims are: a reduction by 50% of the use and risk of chemical pesticides; a reduction of nutrient losses by at least 50% while ensuring that there is no deterioration in soil fertility; a reduction of overall EU sales of antimicrobials for farmed animals and aquaculture of 50% by 2030, reaching 25% of agricultural land under organic farming by 2030.
6. https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000029573022
7. Bundesprogramm ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft
8. https://food-guide.canada.ca/en/ accessed July 10, 2020.

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Availability of Data and material

Provided in the supplementary material

Disclosure statement

No conflict of interest

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