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The use of faba-bean cropping as a sustainable and energy saving technology – A new protein self-sufficiency opportunity for European agriculture?

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Abstract. European agriculture relies on large amounts of imported protein fodder, primarily soya-beans, for livestock rearing from e.g. South and North America. This has severe social and environmental impacts, and require large amount of fossil fuel to cultivate, harvest and transport. This paper investigates how faba-beans - a leguminous crop able to fixate its own nitrogen through symbiosis with soil bacteria while providing various other Eco System Services - can be adopted, as a valuable crop by farmers in EU. This could substitute import of soya-bean for animal fodder, providing global savings in pesticide, artificial fertilizer and fossil energy usage. Emphasizing transition theory and e.g. farm machinery, culture and policies, we conclude, that activities must be applied at all levels of the agricultural system. New transition pathways are e.g. to strengthen farm networks to share knowledge and farm equipment for faba-bean cultivation, and to enhance the environmental regulation to limit the amount of artificial fertilizer distributed on farmland making legumes more valuable for farmers.

1. Introduction

1.1. Impact of modern agriculture

A transition to a more sustainable and energy efficient European agricultural sector is currently challenged by a reduction in the cultivation of legume-based crops (faba-bean, pea, lupine, lenses, grass-clover, etc.), hereunder protein fodder. Despite a policy focus in countries within Europe on the cultivation of legumes, and a diversification of crops being produced, the legume area has declined during the past decades [1], [2]. Over the last 50 years the global average cereal grain yield has almost doubled, but during the same period the cultivation of legumes has dramatically declined, as for example faba-beans, with more than 56 % [3]. This is not a favorable development for the future European agriculture, either on a local or a global scale, due to the many non-harvested benefits that legumes provide for society [4]. The consequences are for example lower Eco System Services (ESS) provided by cultivation of legumes, emphasized below, as well as the need for intensified import of soya-beans from e.g. South and North America. This produce is often genetically modified spices [4], with production strategies causing deforestation and in some cases replacement of native people.

A study conducted by [5] indicate, that system internal outputs of legume nitrogen (N)-fixation of 130-153 kg N per ha can be achieved when cultivating such crops. Other studies point to the same result with variations between 100-200 kg N-fixation per ha [3]. Besides N-fixation legumes also provide crop rotation services, which limit pesticide utilization and costs by up to 25 % for e.g. cereals, and lead to yield enhancement in the following crop by up to 0.2-1.6 t. per ha [5]. ESS's provided by legumes are however highly devaluated for their contribution to establish a more sustainable, self-sufficient and energy efficient European agriculture with lower pressure on 'external' resources. In 2017 European countries for example imported 15 Mt of soya-beans for protein fodder, mainly from South America, second after China, with an import of 93 Mt. China also produced almost 14 Mt.
To put this in perspective Argentina, Brazil and the US produced 53 Mt, 87 Mt and 107 Mt soya-beans in 2017 respectively [6]. According to [7] more than 7.2 M ha forest in South America have disappeared between 1995 and 2005. The Chaco-forest, which cover areas in Brazil, Bolivia and Paraguay, have for example lost more than 10 % of its area, mainly due to cultivation of soya-beans for export and livestock farming [8]. Hence, natural and semi-natural habitats are increasingly converted into arable land, with severe impact on soil quality, climate change and biodiversity [4]. Moreover, large consumption of fossil fuels is connected to the cultivation, harvesting and transport of soya-beans to European countries for rearing of livestock like dairy cattle and pigs, with low feed efficiencies [9].

1.2. Focus of this paper

Environmental benefits and technical possibilities for deploying more legume crops, like faba-beans, have been the focus of several European and international studies and are well described in the current literature [4], [10], [11]. This paper, however, seeks to provide knowledge required for a transition of the European agriculture, with emphasis on stakeholders and organizations constituting the agricultural sector. We will identify embedded norms, cultures and traditions from e.g. Danish farmers, which currently act as obstacles for a further uptake and cultivation of protein legumes - faba-beans for animal fodder - and suggest ways of changing this. Moreover, we will provide policy suggestions to enhance the framework conditions for such changes to take place, which all together can provide more self-sufficiency in protein legume cultivation, and create a more sustainable, energy efficient, diverse and resilient agricultural system [12], largely based on 'internal' European resources.

2. Methodology

2.1. Theoretical approach and data retrieval

With point of departure in Geels' Socio-technical Transition (ST) theory [13] and emphasis on European faba-bean production in a Multi-Level Perspective (MLP) [14], [15] - constituted by the 'landscape', 'regime' and 'niche' levels - this paper develops a platform that facilitates the investigation of a 'transition pathway' for European agriculture to adapt to more legume (faba-bean) cultivation. The findings will highlight in which areas of the coherent *'regime'* (dominating mono-cultural agri-system) that the European faba-bean *'niche'* (new emerging technology or system) are challenging the existing socio-technical system, and how the *'landscape'* level (new policies, trends, consumer pressure, etc.) can impact this development. The perception of ST is to understand the conditions for changes - transitions - as being part of the three analytical levels mentioned, namely 'landscape, 'regime' and 'niche', and to identify *'champions'* [16] (stakeholders capable of influencing transition), who can impact the agricultural sector in the future to support legume cultivation and utilization. Thus, identifying future 'transition pathway's' could provide new 'windows of opportunities' within the dominating European agriculture for a future transition, in which a more sustainable and energy efficient agricultural system could be developed.
Statistical data and policy information data from e.g. public authorities and background reports and publications on European agriculture, as well as materials from organizations like FAO, WRI, etc., has been studied in this paper, and used as secondary data. Knowledge of faba-beans and legumes in

general - technical systems, cultivation practices, ESS, EU policy support schemes etc. - are also retrieved from scientific publications by means of journal articles. Primary empirical data has been collected from Danish agriculture, and utilized as examples of possible 'transition pathways' for European agriculture. Table 1 below shows the eight farmers from where primary empirical data was collected during the month of November and December 2017. Besides a tour around each farm where field notes were taken, the interviews revolved around the farmer's cultivation and utilization of faba-beans, and how different stakeholders in the value chain (farmers, seed producers, feed industry, farmer organizations and farm networks and regulatory frameworks, etc.) impact the current faba-bean situation, and how it can change to intensify faba-bean cultivation. The interviews were approached as qualitative semi-structured interviews, and recorded on tape for use as empirical research data.

Table 1. Type of farmers interviewed and their faba-bean (FB) profile.

Farm type and number	Cultivating FB (own use)	Purchase FB	Sell FB
2 Dairy cattle farmers	1	1	
2 Pig farmers	2		
1 Highland cattle/crop farm			1
1 Chicken farm			1
2 Crop farmers			2

3. Findings and Discussion

In the following section possible 'transition pathways' for adapting to more faba-bean cultivation and utilization in a European context will be outlined. We will emphasize conventional crop farmers and livestock farmers, farm networks, farmer organizations, seed producers and feed industry, as well as suggest relevant agricultural and environmental policies. This section is based on primary empirical data, as well as secondary data, as emphasized in the methodology above.

3.1. Transition pathways for European agriculture

Emphasizing ***conventional crop farmers*** more information and knowledge transfer are needed from farmers successfully working with faba-beans, as far as cultivation systems and practices, fodder quality, pest and weed control, etc. This is needed to increase the awareness and break down unfavorable myth of faba-bean cultivation. For ***conventional livestock farmers*** the question of knowledge transfer, as well as stronger cooperation, is a main issue [3]. Therefore, knowledge about the nutritional value of faba-beans and fodder mixes must increase, and farmers should to a higher extend share storage capacity and new types of farm equipment facilitating faba-bean cultivation. The latter has proved important in the Danish situation. Thus, new farms could also be established with storage capacity for fodder legumes applied already when constructed. Faba-beans can be utilized for pig fodder without any pre-treatment than grinding, but this knowledge need to be disseminated. Mobile grinders for pig fodder, and toasters for cattle feed, could eventually be rented, and the possibility for this could be disseminated more among farmers.

Farm networks play a pivotal role to achieve the above and to sustain a further development of the faba-bean 'niche', future network activities by these stakeholders must be strengthened. Enhancing farm networks in which farmers disseminate and share knowledge about legumes among each other is highly needed, and will provide good pilot cases for farm visits, sharing of machinery and storage capacity. Buying/selling faba-beans among each other could e.g. be facilitated by means of electronic platforms and increased communication between farmers in general, etc. Such pressure on the 'regime' from the 'niche' is constituted by the organic faba-bean farmers today, but must be strengthened in the future. This 'incubation center' (see [13], [15]]), composed by the 'niche', should ideally be supported by ***farmer organizations***, but this is challenging as these organizations have an embedded reluctance to change the current 'regime'. It is, however, important that farmer organizations continue and expand their existing - albeit limited - work on legumes, hereunder faba-

beans, as this shape and impact the entire 'regime' of the agricultural sector. Farmer organizations are the 'champion' most reluctant to change as they constitute the agricultural sector, being strongly impacted by traditions and culture and provide the direction for it. Changes will most likely come about slowly and require a paradigm shift from the 'landscape' level by changes in the university colloquium of researchers and staff connected to the agricultural sector, as well as for conventional farmers at farm-schools. In combination with higher environmental awareness in the society as a whole, this could impact the development.

Both ***seed producers*** and the ***feed industry*** are important 'champions' for a transition toward more legume cultivation in Europe, and do not grant legumes high interest in the agro-industrial supply chain [11]. Both stakeholders must continue their present work on developing and refining faba-bean cultivars appropriate for cultivating in Europe, as well as providing a platform for buying and selling faba-beans. The need for better cultivars supplied by these stakeholders, are also stressed by [11], which could provide higher added value and increase the interests in legumes. These 'champions' could potentially be more flexible to a changing 'regime', as they would like to sustain market shares. If protein trade among farmers intensifies, which could be facilitated by the farm networks, mentioned above, changes in the existing socio-technical system could appear relatively fast. As of now, farmers in e.g. Denmark sell and buy faba-beans among each other and achieve economic benefits, compared to selling/buying from the fodder industry. Prices of for example wet and dirty faba-beans are sold between local farmers at more favorable prices than the feed industry are willing to pay.

If protein trade among farmers intensifies, and the arable land being cultivated with faba-beans increase, seed companies could see advantages and might be more interested in participating in order to gain and sustain market shares. Stronger farm networks might also directly put pressure on the 'regime', as to develop new and more suitable faba-bean seeds appropriate for the European context, instead of farmers - like in Denmark - joining forces and buying seeds abroad. As for the farmer organizations, both seed and fodder industries could benefit from new learning colloquium at the 'landscape' level, which could facilitate changes in the 'regime', as embedded traditions and cultures - difficult to change - could be untightened. New consumer requirements at the 'landscape' level of more organic protein fodder being used for livestock's in Europe could also increase the price of soya-beans. Together with more emphasis on legumes for human consumption (food), it would make it more economically favorable to cultivate legumes for protein fodder and human food.

When it comes to ***agricultural & environmental policy*** it would benefit the balance of for example Danish agriculture, if the 'harmony rule' was re-introduced. This could potentially lead to farms becoming more balanced in the size of land and number of animals (e.g. bio-dynamic farming), as before the intensive monoculture monopolized the agricultural 'regime', where mixed farming systems were more widespread [11]. Better frameworks for becoming self-sufficient, or at least increase the faba-bean yield, could be a result of this. Stronger environmental regulatory frameworks supporting the growing of legumes for N-fixation, and increase in the cultivation of domestic protein fodder, could also be exercised. Such pressure from the 'landscape' should be adapted through agricultural and environmental policies, and would promote an intensified cultivation of legumes.

4. Conclusion

European agriculture is mainly composed of mono-cultures - primarily cereals like wheat - and a massive use of 'external' resources like artificial fertilizer N, pesticides, fossil fuels, and large import of protein fodder like soya-beans, constantly fed into the system to sustain it. This paper investigates how to increase the faba-bean cultivation and consumption within Europe to achieve ESS's and energy savings, etc. Secondary data and primary empirical data collected from farmers revile the importance of supporting activities within and create stronger farm networks at the *'niche'* level. A 'transition pathway' is thus to enhance farmer activities through farm networks, as such networks constitute a potential role as *'champion'*. Farm networks should increase in numbers and strengths and disseminate knowledge about faba-beans cultivation and utilization as fodder etc. They should also intensify the sharing of farm equipment, storage facilities and increase the trade of protein fodder among farmers.

Such *'niche'* activities could intensify the pressure on the *'regime'*, and the uptake of faba-beans in the existing agricultural system. Pressure from the *'landscape'* level - by changes in the learning colloquium of for example researchers and staff connected to farmer organizations, of seed and fodder companies, as well as of farm-schools - should also be applied. Compared to fodder and seed industries, which have a build-in flexibility as far as creating and sustaining market shares, we find that farmer organizations are the *'champion'* most reluctant to adapt to changes, and with the highest interest in sustaining the existing '*regime*'. Pressure from the *'landscape'* level could also be exercised by consumer groups requiring more sustainable and organic fodder for European livestock, as well as legumes for human consumption. Also, stronger agricultural policies where 'harmony' between farmland and the number of animals are needed. This would provide an opportunity for higher level of self-sufficiency in the protein supply in Europe. Lower amounts of N-fertilizer being used on farm soil - through stronger environmental policies - could also enhance farmers' cultivation of legumes to fixate nitrogen, and hence achieve other ESS benefits. Thus, different activities must be taken by various stakeholders connected to European agriculture, at all levels investigated here, for a transition to emerge.

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