Legumes Translated Report 4

Continental and global effects

Donal Murphy-Bokern

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Legumes Translated

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Introduction

The overall goal of Legumes Translated is to support the diversification of European cropping systems through linking research- and practice-based knowledge relevant to the production and use of legumes. The diversification of European cropping to grow more grain legumes raises the question of what are the wider global environmental and economic effects. The purpose of the work reported here is to consider the potential large scale effects of changing European cropping systems. Environmental effects at the continental and global level need to be considered alongside effects at the national and local level. The scope and resourcing of the Legumes Translated does not enable a deep investigation into the effects of changes in cropping systems on global markets and land use. It was decided to focus on existing production and trade data to examine the effects of different scenarios, with some support from information gathered from actor groups in the project and from the literature.

The large scale effects of increasing legume production depend on changes in the supply and demand of the relevant commodities, especially imported soybean and exported wheat. The amount of land needed to support Europe's agri-food system as affected by increasing grain legume production is a key consideration. The effect on the use of synthetic nitrogen fertiliser is also important. These were investigated by extracting data for the production of grain legumes and the major cereals over the decade up to 2017, using the FAOstat data base for the 28 members of the European Union, i.e., the EU 28 including the United Kingdom. The data were subjected to simple modelling of eight change scenarios.

Scenarios and assumptions

The data were extracted from the FAOSTAT database in August and September 2021. The baseline is mean annual areas and yields of all grain legumes, wheat and barley, and other relevant data for the European Union, i.e. the EU 28 (all member states including the United Kingdom) in the decade 2008 and 2017.

The average grain legume area in the decade 2008-2017 was 2.29 million ha or 2.1% of the EU's arable area. There was a steady rise through the period reaching 3.3% of the arable area in 2017. This compared to 17.5% for the global arable area occupied by legumes in 2019.

The current situation

The current stand (average of 2008 to 2017) was set out in a simple model using Microsoft Excel. This converted the production of grain legumes and the leading cereals (wheat and barley) into units of protein (tonnes) and metabolisable energy (megajoule (MJ) and gigajoule(GJ)). The metabolisable energy for growing pigs data from Feedipedia was used as a proxy for all monogastric feed and for food purposes. The assessments were done on faba bean, lupin, pea, soybean with other species such as chick pea, lentil and vetch grouped as 'other legumes'. Together these produced an average of 1.441 million tonnes of protein annually, compared with 16.2 and 6.14 million tonnes from wheat and barley respectively. The legumes produced 92.3 million GJ of metabolisable energy compared with 1986.1 and 795.2 million GJ from wheat and barley respectively. On this basis, the starch and the energy value of the extra protein produced with increased grain legumes is compared with that of the reduced output of cereals (represented by wheat and barley) using the common currencies of protein and metabolisable energy. It is noteworthy that the yields of all legume crops in the EU is higher than the global average. With the exception of soybean grown in Brazil, EU grain legumes yields are higher than in countries that export grain legumes to the EU. The average yield of EU soybean is slightly lower than in Brazil.

Nitrogen use

The nitrogen (N) fertiliser requirement of grain legumes is assumed to be zero. The N requirement of cereals is 20 kg/t for wheat and 18 kg/t for barley. This reflects current fertiliser recommendations systems for the purpose of this model and approximates the nitrogen off-take in the grain.

Pre-crop effect

The yield of cereal crops grown after legumes is higher than the yield of cereals after cereals. This is the pre-crop effect due to a range of factors affecting the nutrition of the subsequent crops and the incidence of diseases, especially root diseases. The model assumes that wheat is the first crop after the legume and that the yield is 25% higher than the average yield of wheat (from Peoples et al.[1]) This is a proxy for all pre-crop effects of introducing grain legumes into the arable cropping system.

Protein and energy contents

The assumed protein and monogastric metabolisable energy contents (for growing pigs) are set out in Table 1.

[1] Peoples M. B., Hauggaard-Nielsen H., Huguenin-Elie O., Jensen E. S., Justes E., Williams M. 2019. The contributions of legumes to reducing the environmental risk of agricultural production. In: Agroecosystem diversity: Reconciling contemporary agriculture and environmental quality. Lemaire Gilles (ed.), De Faccio Carvalho Paulo César (ed.), Kronberg Scott (ed.), Recous Sylvie (ed.). Londres : Academic Press, pp. 123-143. https://doi.org/10.1016/B978-0-12-811050-8.00008-X

Table 1. Crop productivity values used in the model based on the average yields in the EU 28 in the decade 2008 to 2017. All values relate to crops with 14% moisture content. Metabolisable energy (ME) is for growing pigs. Yield data are from FAOstat and nutritional values are from Feedipedia.

Crop	**Yield (t/ha)**	**Protein concentration (%)**	**ME (MJ/kg)**	**Protein yield (t/ha)**	**ME yield (MJ/ha**
Faba bean	3.10	25.0	14.9	0.775	47,616
Lupin	1.51	30.0	14.7	0.453	22,197
Pea	2.61	20.6	15.5	0.538	40,455
Soybean	2.77	34.1	19.5	0.945	54,015
Other legumes	2.13	21.0	15.1	0.447	32,163
Wheat	5.55	11.1	13.6	0.616	75,480
Barley	4.67	10.4	12.5	0.486	58,375

The following scenarios were examined using the simple model:

1. A three-fold increase in grain legumes in the current proportions of legume species, displacing wheat (3x).
2. A three-fold increase in grain legumes through increasing soybean, faba bean and pea, displacing wheat (3x – SFP).
3. A three-fold increase in grain legumes in the current proportions of legume species, displacing wheat, with a pre-crop effect (3x - PCE).
4. A three-fold increase in grain legumes through increasing soybean, faba bean and pea, displacing wheat, with a pre-crop effect (3x – SFP - PCE).
5. A five-fold increase in grain legumes in the current proportions of legume species, displacing wheat and barley (5x).
6. A five-fold increase in grain legumes through increasing soybean, faba bean and pea, displacing wheat (5x – SFP).
7. A five-fold increase in grain legumes in the current proportions of legume species, displacing wheat and barley with a pre-crop effect (5x - PCE).
8. A five-fold increase in grain legumes through increasing soybean, faba bean and pea, displacing wheat, with a pre-crop effect (5x – SFP).

Results

Production-related outcomes for each scenario are presented in Table 2. All scenarios result in an increase in the production of protein and a reduction in the production of metabolisable energy due to the increase in the production of legumes. The protein increase ranges from the equivalent of 0.509 million tonnes soybean from Scenario 1 to 8.4 million tonnes for a five-fold increase in legume production to 10.4% of the arable area (Scenario 8). The reduction in energy production for a five-fold increase in legumes ranges from the equivalent of 11.7 to 22.7 million tonnes of wheat. The balance between reduced production of metabolisable energy and increased production of protein ranges from 21 tonnes of wheat equivalent less per tonne of soybean equivalent gained to 1.38 tonnes of wheat less per tonne of soybean gained.

The EU is a net exporter of cereals. FAOStat trade data for 2008–2017 show that average annual net export was 17 million tonnes, mostly wheat. The results show that diversification of the European cropping system using high performing grain legumes up to 10% of the arable area can be achieved without resulting in structural deficit in cereals. Very broadly, the metabolisable energy production using the assumptions here declines by about 1 million tonnes of wheat equivalent for every 1% increase in grain legume production.

Overall, the land required to support the EU's food system (the net land area footprint) increases with increasing production of legumes as modelled. The increase ranges from 318,479 ha for Scenario 8 (the most effective five-fold option) to 6.035 million ha for Scenario 5 (the least effective five-fold option). The land area needed outside the EU to compensate for the reduced export of cereals, especially wheat, is greater than the land area in soya exporting countries saved by the increased protein production in the EU.

This global land use balance, which is crucial to indirect environmental effects (land use change) is affected by the yield of the legumes and their effect on the yield of the following cereal crop. The positive pre-crop effect of a legume on the yield of subsequent crop is a crucial factor in determining the global effect.

Table 2. Changes in protein and metabolisable energy (ME) production of grain legumes, wheat and barley in the EU 28 as affected by eight legume production scenarios.

Scenario	**Description**	**Protein production (million tonnes)**	**Energy (million GJ)**	**Protein change: soybean equivalents (million tonnes)**	**ME change: wheat equivalents (million tonnes)**	**Change in nitrogen fertiliser requirements (tonnes)**
	Baseline	23.79	2,874			
1.	3x	23.96	2,726	+0.509	-10.83	-707,000
2.	3x-SFB	24.33	2,748	+1.621	-9.26	-707,000
3.	3x-PCE	24.51	2,794	+2.120	-5.88	-608,000
4.	3x–SFB-PCE	24.88	2,815	+3.213	-4.31	-608,000
5.	5x	24.71	2,565	+2.706	-22.72	-928,000
6.	5x–SFB	25.46	2,607	+4.892	-19.58	-928,000
7.	5x–PCE	25.93	2,714	+6.284	-11.73	-708,000
8.	5x–SFB-PCE	26.68	2,757	+8.470	-11.69	-708,000

Conclusions

These results indicate that the EU can increase protein production by expanding legume cropping without causing a net deficit (net import) in cereals. Replacing cereals with legumes increases protein production. This can be seen as positive. However, the changes modelled here increase the net land area required to support the European food system which results indirectly in land outside the EU being used to make up for the reduced cereal imports. There are some simplifications in this investigation which must be noted. ME in starch-based carbohydrate is considered the same as ME in oil. In reality there might be adjustment through the trade for oil and cereals. Effects on amino acid profiles were not been looked at. But the overall message is clear and reliable: aligning our cropping systems to an ecologically appropriate proportion of high-performance grain legumes (10%) will reduce the import of high-protein materials by the equivalent of 25% of the current soya import.

A European agricultural system with 10% grain legumes in the arable area would use about 7% less nitrogen. In this model, the pre-crop nitrogen residue is used up by the extra yield potential of the remaining cereal crops so that the effect on total N fertiliser use is tightly linked to the legume area rather than to carry over effects on total fertiliser applications.

It should be kept in mind that this analysis is based on replacing wheat and barley with grain legumes using data for averages across the EU. The results show that the overall outcome is very sensitive to the relative yields of the displaced and displacing crops. In reality, the displaced crops are likely to be lower yielding then the average and the optimum displacing legume crop will be chosen in each situation. This has the potential to raise the performance above that modelled here to the point where the change is neutral in terms of global land use. A positive global environmental case for increasing grain legume production in Europe depends on the performance of these crops compared to the crops they replace. If we in Europe opt to expand legume cropping to reduce our dependence on imported protein, it is essential that we use productive legumes to displace relatively low yielding crops in current systems. The methodology used here can be applied to local data sets and to scenarios where legume production expands by replacing relatively low yielding crops. Improving the on-farm resource capture performance of the displacing legume crops is key.

In the context of a wider protein transition that increases the EU's protein autonomy and disconnects the EU from deforestation, the changes outlined above would be complemented by increased imports of soybean from other European countries (e.g., Ukraine) and especially by increased efficiency of the use of other protein sources. The biggest effect would come from a reduction in livestock production enabled by dietary change.

In considering the investigation reported here, it must be kept in mind that it is based on cropping changes at the combined European Union and United Kingdom level (EU28) assuming that average yielding wheat and barley is displaced by grain legumes. In reality, the expansion of legumes will displace relatively poorly performing non-legume crops with relatively productive legume options. Simulating this requires more detailed assessment of local crop production data sets.

About this report

Author: Donal Murphy-Bokern, http://murphy-bokern.com/

Contact: Donal Murphy-Bokern, donal@murphy-bokern.com

Production: Donau Soja

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