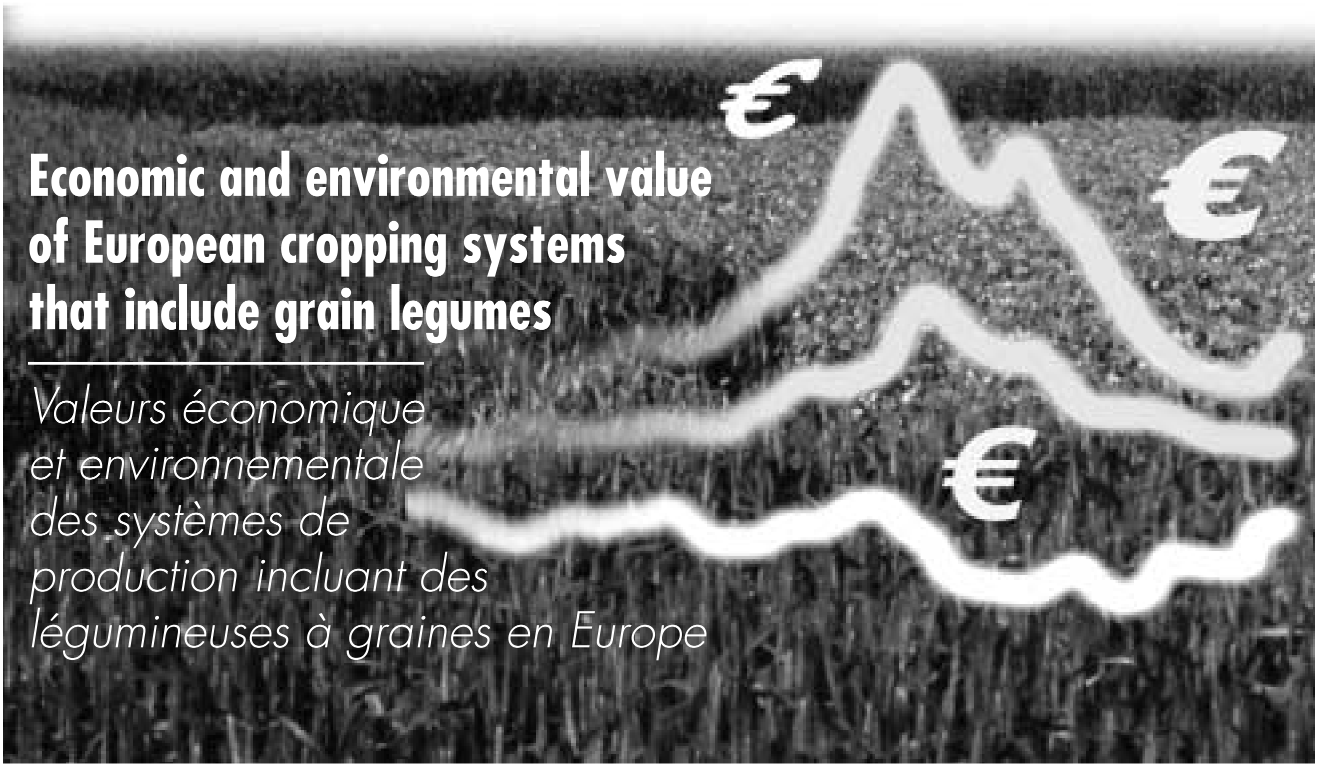

(Photo composition A. Mauffret, photos UNIP, France)

Economic and environmental value of European cropping systems that include grain legumes

Valeurs économique et environnementale des systèmes de production incluant des légumineuses à graines en Europe

Grain legume crops could offer many economic and environmental benefits if they were to be grown more widely in European crop rotations. The potential for increase would be great since grain legumes, such as peas, faba beans and lupins, represent only 1%–7% of the arable crops area in the EU, compared with 15%–25% outside Europe.

Grain legumes are particularly relevant for sustainable cropping systems as shown by the results of economic and environmental studies undertaken within the scope of the Concerted Action GL-Pro[1] supported by the EU.

The first article of our special report describes the bottlenecks and prospects for grain legume cultivation and use in different European regions, discovered from questionnaire surveys with more than 500 farmers that do not grow grain legumes.

The economic and environmental benefits of grain legumes in crop rotations in some regions of France, Germany, Spain and Switzerland are presented in the following two papers. Crop rotations with and without grain legumes were compared in terms of their rotation gross margin in each region. Their impact on the environment in terms of energy consumption and greenhouse gas emissions has been evaluated by Life Cycle Assessment (LCA).

This distinctive twofold approach, comprising economic calculations and LCA, is based on the same data sets. It enables a comprehensive eco-environmental interpretation for a specific region and, in addition, the approach meets the increasing demand of society to evaluate cropping systems not only in terms of profitability but also sustainability and environmental impact. ■

[1]European extension network for the development of grain legume production in the EU (QLK-CT-2002-02418)

Les légumineuses à graines pourraient offrir plusieurs avantages économiques et environnementaux si ces cultures étaient plus importantes dans les rotations européennes. Le potentiel de développement est réel car les légumineuses telles que le pois, la féverole et le lupin ne représentent que 1%–7% des surfaces arables de l'UE, alors que la part des légumineuses à graines peut atteindre 15%–25% à l'extérieur de l'Europe.

Ces cultures sont particulièrement adaptées aux systèmes de production durables comme le montrent les résultats des analyses économiques et environnementales de l'Action Concertée européenne GL-Pro[1] financée par l'Union européenne.

Le premier article de notre dossier se base sur un questionnaire adressé à plus de 500 agriculteurs qui ne cultivent pas ou plus de protéagineux ou autres légumineuses à graines afin de décrire certains points critiques et prospectives pour la production et l'utilisation de légumineuses à graines.

Les deux articles suivants analysent les bénéfices économiques et environnementaux de l'inclusion des légumineuses à graines dans les rotations de cultures de plusieurs régions de France, Allemagne, Espagne et Suisse. La comparaison des rotations de cultures avec et sans légumineuses à graines est basée sur la marge brute de la rotation dans chaque région. L'impact sur l'environnement en terme de consommation d'énergie et d'émissions de gaz à effet de serre est évalué par l'Analyse du Cycle de Vie (Life Cycle Assessment, LCA).

Ces deux approches parallèles, calculs économiques et LCA, sont basées sur la même série de données de références. Cela permet une interprétation éco-environnementale globale pour une région donnée, et cela répond à la demande croissante de la société d'évaluer les systèmes de production non seulement en terme de profit économique mais aussi en terme de durabilité et d'impact environnemental. ■

[1]European extension network for the development of grain legume production in the EU (QLK-CT-2002-02418)

What do European farmers think about grain legumes?

Que pensent les agriculteurs européens des légumineuses à graines?

by Julia-Sophie von Richthofen and GL-Pro partners*

About 1.4 million ha of field peas, faba beans and lupins were cultivated in 2005 throughout the EU, leading to a production of about 4 million tonnes (t). This amount contributes only 4% of the European consumption of protein for the feed industry.

Although grain legumes could offer many benefits in European crop rotations, they constitute only 1% to 7% of the arable crops area in the different European countries, compared with 15% to 25% outside Europe (data includes soyabeans) (1). Furthermore, in north-west Europe the cultivated area of grain legumes is decreasing (Table 1).

Compared with 2004, European farmers reduced the pea area by 62,000 ha (–7%) to 811,000 ha in 2005. Especially in France and Germany the area decreased to 311,000 ha (–12%) and 111,100 ha (–9%), respectively. In Denmark the reduction was particularly dramatic (about 40%): only 16,000 ha were grown in 2005 compared with 27,000 ha in 2004.

Against this trend in north-west Europe, Spanish farmers once again grew more field peas, increasing the area by 8% in 2005 to 147,000 ha. However, due to the long severe drought in spring and summer the national production was only about 120,000 t, which was 60% of the previous year's production.

In contrast with pea, the European faba bean areas continued to increase, reaching a total of 446,000 ha in 2005 (+11%). In France the acreage increased by 21,000 ha (+26%) to a total of 102,000 ha.

A survey of non-producers

To find out why European farmers do not grow more grain legumes and to determine the problems and prospects for grain legume production a questionnaire was sent to European farmers who had never grown grain legumes or who had stopped grain legume cultivation. This survey was supported by the European Commission within the framework of the Concerted Action GL-Pro.

In the winter of 2004/05, 553 farmers from Belgium, Denmark, France, Germany, Spain and Switzerland answered the questionnaire. The majority of farmers filled in a written questionnaire, but some interviews also took place based on the same questionnaire. Table 2 and Figure 1 on page 16 show the regions covered by the survey.

The French surveys were the end-study projects of students from three French agricultural schools (ISA Lilles, ESA Angers, ESITPA Rouen) and these were carried out in the regions of Barrois, Bretagne and Beauce-Gatinais using a modified questionnaire. For this reason the results were not integrated directly into the analysis.

The percentages of returned questionnaires and the sizes of the study areas covered by the survey differed from region to region. This has to be taken into consideration when the results are discussed. In Denmark only four non-producers answered the questionnaire and their answers were not included in the analysis.

Grain legumes are seen as less profitable

Farmers were asked their main reasons for not growing grain legumes and were offered a choice of answers to a series of different statements (Table 3).

In Belgium, Germany, Spain and Switzerland, farmers usually named the lack of competitiveness of grain legumes compared with potatoes, sugar beet and cereals as the main obstacle. The lack of ability to compete with an alternative break crop, namely oilseed rape, was also a sound reason for German and Swiss farmers. Market price, grain yield and the risk of yield fluctuations are therefore the major obstacles.

The same reasons are of concern for farmers surveyed in France. In contrast with their European colleagues, however, they stressed the high seed costs as an important constraint for grain legume production.

Table 1. Areas of field peas, faba beans and lupins in GL-Pro partner countries (1,000 ha).

	2000	2001	2002	2003	2004	2005
Belgium	1.7	1.9	1.6	2.1	2.1	1.9
Denmark	35.6	32.1	40.4	31.4	26.7	16.0
France	461.3	473.6	431.0	456.0	444.5	420.4
Germany	181.6	218.6	206.9	201.5	172.8	165.7
Spain	70.3	72.4	132.7	163.2	199.7	213.9
Switzerland	3.0	3.3	4.4	5.4	4.9	5.3

Source: UNIP, Paris, France; EUROSTAT; swiss granum (www.swissgranum.ch)

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Table 2. Participation of grain legume (GL) non-producers in the GL-Pro survey.

	Belgium	France*	Germany	Spain (Central) Castilla/Leon	Spain (North) Navarra	Switzerland (West)
Coordinating institution	APPO	ARVALIS/UNIP	proPlant/TUM	ITA	ITGA	Agroscope RAC Changins
Number of GL non-producers surveyed	62	170	159	36	38	84
Percentage of farmers who grew GL in the past	44%	64%	62%	75%	84%	64%

*Interviews in Barrois, Beauce-Gatinais and Bretagne in cooperation with agronomic schools based on a modified questionnaire.

Furthermore many farmers described the threshing of grain legumes as problematic. In particular, the farmers of Barrois in France emphasised harvesting problems.

Regional differences in opinion

The survey also revealed some regional differences in farmers' opinions about the specific reasons that limit the development of grain legume production. Farmers in Flanders, the north-western part of Belgium, argued against peas because of the serious pigeon damage that they experience every year in their fields. In Bretagne, owners of intensive pig farms with high livestock densities cannot expand grain legume production because of nitrate regulations.

In western Switzerland grain legumes compete with other break crops (sugar beet, potatoes, rapeseed) in rotations. Moreover, ley farming and temporary meadows play an important role in Swiss agriculture. Compared with many European cropping systems, the rotations are more varied: about 45% of the crop rotations mentioned by farmers are five years or longer.

Farmers know benefits for the following crop

In the GL-Pro surveys farmers were also asked to give their appraisal of grain legumes. Many of them had grown peas, faba beans or lupins in the past (Table 2) and had some experiences with these crops.

Table 3. Grain legume non-producers: reasons not to grow grain legumes.

Reasons[1]	Mean agreement/disagreement[2] Belgium	Germany	Spain (Central) Castilla/Leon	Spain (North) Navarra	Switzerland (West)
Not competitive with sugar beet/potatoes	3.5	3.1	3.6	1.0	3.1
Low/fluctuating producers' price	3.3	3.1	2.8	2.9	2.6
Not competitive with cereals	3.1	3.1	2.8	3.5	3.0
Unstable yields	3.1	3.2	3.0	3.7	3.0
Low yields	3.0	2.8	3.3	3.1	2.9
Harvesting problems	3.0	2.7	2.7	2.5	2.9
Insufficient CAP subsidies for protein crops	3.0	2.6	2.9	2.9	2.5
Damage by pigeons	3.0	2.1	2.3	1.0	1.5
Insufficient regional support	2.9	2.5	2.7	2.3	2.4
High seed costs	2.6	2.6	2.8	1.9	2.2
Not competitive with oilseeds	2.3	3.2	2.7	2.4	3.0
Lack of adapted varieties	2.2	2.1	2.2	2.3	2.4
Difficult to market	2.1	2.6	2.2	1.4	1.7
Problems with herbicides (availability/efficiency)	2.1	2.3	2.7	1.7	2.1
Not adapted to climate	2.1	1.7	1.7	1.8	2.2
Work organisation	2.0	2.0	2.1	1.8	1.8
Problems with pests	2.0	2.1	2.1	1.9	2.2
Nitrogen regulation	1.9	2.1	1.3	1.3	1.7
Problems with specific diseases	1.9	2.1	1.9	2.5	2.0
Not adapted to soils	1.7	1.7	2.2	1.6	1.9
Problem with root diseases in peas	1.7	1.9	1.7	1.6	1.9

[1] Sorted by agreement in Belgium (descending).
[2] Mean agreement/disagreement calculated from the possible answers: absolutely sure: 4, rather sure: 3, rather not: 2, surely not: 1.

Farmers agree on agronomic benefits

Most farmers interviewed were in agreement that grain legumes are precious feedstuffs, rich in protein and energy. However, many of them were not aware of their monetary value, i.e., that the on-farm feeding value of a farmer's own pulses is higher than the market price.

When asked about the impact of grain legumes in crop rotations, the farmers interviewed said that they regarded grain legumes as good break crops, improving soil fertility and leading to high additional grain yields of the following crop. On average they estimated, that wheat after grain legumes produces 0.6 to 0.9 t/ha more yield, compared with wheat after cereals (Belgium, central Spain and Switzerland +0.6 t/ha, Germany and northern Spain 0.9 t/ha, French farmers approved but did not quantify the yield gain of cereals after grain legumes).

Higher producers' prices and greater support for protein crops would be primary incentives for farmers to take up grain legume production, but this would interfere with CAP reform regulations. High yielding varieties, resistant to lodging associated with easier threshing are also classified as important.

For farms with dairy and suckler cows in Bretagne and Barrois an on-farm supply of protein feed is a substantial argument for grain legumes, providing the benefits of traceability, GMO-free feed.

According to some farmers, the reform of the sugar market regulations, with decreasing profitability for sugar beet cultivation, might provide a reason for replacing some sugar beet with grain legumes.

In conclusion, most of the farmers surveyed appreciated the agronomic advantages of grain legumes in crop rotations and their feeding value, but their choice of crops was determined mainly by yield and price. Compared with the gross margins of other important arable crops, especially rapeseed and wheat, grain legumes are seen as less profitable. In the following article we show that this is not the case when gross margins are compared at the rotation level; in fact economic analysis cannot be limited to the crop level in a cropping system. ■

(1) GL-Pro (2005). Guidelines for growing grain legumes in Europe. GL-Pro, UNIP, Paris.

Economic impact of grain legumes in European crop rotations

Impact économique des légumineuses à graines dans les rotations culturales en Europe

by Julia-Sophie von RICHTHOFEN and GL-Pro partners*

With technical progress in soil tillage, fertilisation and plant protection, the agronomic significance of crop rotation design and consequently the preceding crop effects of grain legumes have become less and less significant for farmers than in previous decades, while the competitiveness of the single crop has come to the fore. Very limited crop rotations have been developed, dominated by high yielding winter cereals, and this happened, even though the preceding value of grain legume crops seems to be well known. Their benefits for the following wheat compared with a preceding cereal crop can be summarised approximately as follows (1):

- Average additional grain yield: 0.5 – 1 t/ha,
- Reduction of N-fertilisers: –20% to –25%,
- Reduced pesticide costs: –20% to –25%,
- Reduced operation costs for tillage (no plough): –25% to –30%.

Decreasing proceeds (yield in t/ha x price in €/t) of cereals, increasing costs of N-fertiliser and fuel as well as the increasing size of farms and the increasing machine capacities required are weighty reasons supporting more diversified rotations. To study the economic feasibility of grain legumes in crop rotations was therefore the target of the GL-Pro network. The average crop rotation gross margin per hectare and year served as a key figure, since it is only the analysis of whole rotations that allows a correct and acceptable economic evaluation of grain legume cropping.

Figure 1. Regions chosen for the GL-Pro studies.

Figure 1 shows the regions that were chosen for this GL-Pro target. The main climatic and soil characteristics for some of these regions and the percentage of grain legumes in the arable land area are given in Table 1. This shows that grain legume cropping varies greatly in importance in these parts of Europe.

Rotation gross margin is crucial

For each region a typical arable rotation, including cereals and oilseeds, was identified. This rotation was then diversified with grain legumes. Using common methodology and hypotheses, all the data required to assess the gross margin of each crop in the rotations were compiled. A prospective approach was taken, considering reform of the Common Agricultural Policy (CAP), and taking only coupled payments into account. Based on these criteria, the rotation gross margins were calculated and compared. For more information about the methodology of this model see Inserts 1 and 2 on page 19. In the following sections some results are presented and discussed.

For Saxony-Anhalt in East Germany and the Barrois region in eastern France, the five-, four- and three-year rotations:

- oilseed rape–winter wheat–winter wheat–winter wheat–winter barley (80% cereals),
- oilseed rape–winter wheat–winter wheat–winter barley (75% cereals) and
- oilseed rape–winter wheat–winter barley (67% cereals)

were compared with the grain legume rotation oilseed rape–winter wheat–peas–winter wheat–winter barley (60% cereals).

The average grain yields of cereals and oilseed rape in the two regions obtained by farmers over the period 2000–04 were quite different: in Saxony-Anhalt rapeseed

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Table 1. Main characteristics of some study regions.

	South		Central			North	
	Navarra (North Spain)	Castilla y León (Central Spain)	Barrois (F)	Picardie (F)	Canton Vaud (CH)	Saxony-Anhalt (D)	Fyn (DK)
Annual average temperature (°C)	13	11	10	14	8	9	8
Annual average rainfall (mm)	600–800	400–500	730	600–700	850	400–500	450–600
Soil	Calcareous clay	Calcareous clay	Calcareous clay (+ stones)	Calcareous loam	Heterogeneous	Loam	Sandy loam
% of grain legumes in arable land (2004)	3*	4	1.4	6.4	3	3.3	1

* Non-irrigated areas. Source: GL-Pro partners.

yielded 3.5 t/ha and cereals yielded about 7.5 t/ha, compared with 3.0 t/ha and about 7.0 t/ha, respectively, in Barrois. There the advice is to produce winter peas, whereas in Saxony-Anhalt only spring peas are grown. In both regions pea yields were similar. Farmers obtained yields of about 4.0 t/ha on average with the respective pea types.

Diversifying the cereal rotations with peas had a favourable effect on the rotation margin. In Saxony-Anhalt its margin was €289/ha which is €29/ha (11%) higher than the margin for the five-year rotation with 80% cereals (Figure 2). Compared with the four-year rotation the advantage was still €11/ha (4%).

In Barrois farmers gained comparable economic benefits. The five-year rotation fell behind the pea rotation by 7% (–€25/ha). The four-year rotation, oilseed rape–winter wheat–winter wheat–winter barley, had a 5% lower gross margin (–€17/ha).

These results can be explained as follows: in Germany the market proceeds of the pea rotation fell below the proceeds of the five- and four-year cereal rotations by approximately 5% (about –€40/ha). Even the coupled premium for protein plants (€55.57/ha) did not compensate for this difference in the average of the rotation. In Barrois, however, the average market proceeds of the pea rotation were only about 2% lower. Here the greater competitiveness of winter peas compared with cereals and rapeseed in eastern France was evident: peas to cereal ratios for yield were about 1:1.7 in Barrois and 1:1.9 in East Germany, while peas to rapeseed ratios were 1:0.7 and 1:0.9, respectively.

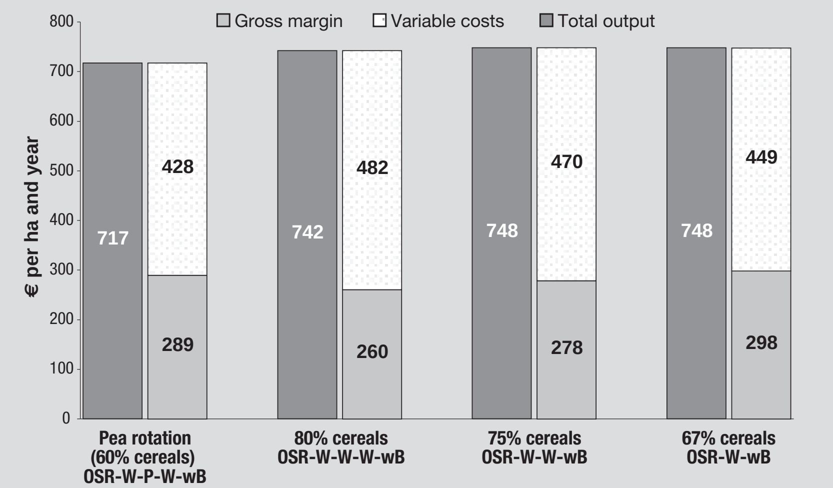
When considering also the coupled premium for peas and the re-coupled area payment, farmers in Barrois on average had an equivalent total output[1] when the percentage of cereals in the rotation was reduced to 60%.

An analysis of the production costs revealed that in Saxony-Anhalt more than €50/ha on average was saved when using the pea rotation compared with the five-year cereal rotation and about €40/ha was saved compared with the four-year rotation. Pea cropping was cost-efficient, although the seed was expensive and the costs of threshing were higher than for cereals. However, the following wheat was produced much more cheaply than when wheat followed wheat: a saving of 30 kg N fertiliser/ha, no extra treatments against grass weeds or special fungal diseases, and minimum tillage (without plough), amounting altogether to about €100/ha fewer variable costs.

In the German region it meant that on average, the lower proceeds of the pea rotation were more than compensated for by the saving on production costs.

In Barrois the cost savings were not so high, because winter peas are managed more intensively. For example three weed treatments and two fungicide and insecticide applications are usual, but costs of about €20/ha could be saved compared with the rotations with a high percentage of cereal.

When the more common three-year rotation of rapeseed–winter wheat–winter barley was compared with the diversified pea rotation, thereby reducing the percentage of cereals from 67% to 60%, the margin differences of the two rotations



OSR = oilseed rape, P = spring pea, W = winter wheat, wB = winter barley.

Components of the total output:
– Average yields and selling prices 2000–04 (OSR: 3.5 t/ha, €210/t; P: 3.8 t/ha, €123/t; W: 7.4 t/ha, €104/t; wB: 7.5 t/ha, €92/t).
– Coupled CAP payments from 2005 (€55.57/ha for protein crops).

Components of the variable costs:
– Seed, fertiliser, plant protection, hail insurance, grain drying, variable machine costs, calculatory interest.
– Crop management measures and prices for supplies according to crop season 2004.

Figure 2. Economic comparison of crop rotations in Saxony-Anhalt, Germany (CAP reform scenario 2005).

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were only minimal. The average annual margin for the pea rotation was €9/ha lower in Saxony-Anhalt and only €4/ha higher in Barrois than for the common three-year rotation.

Similar results were obtained when the same crop rotations were compared in Picardie (France) and the island Fyn (Denmark). Largely because of the high pea yield potential in these regions – an average of 5.2 t/ha in Picardie and 4.5 t/ha in Fyn for the period 2000–04, rotations with spring peas are competitive when compared with rotations dominated by cereals.

Spain: sustainable rotations with 17–25% grain legumes

In Spain the GL-Pro studies were in the more humid areas in the North (Navarra) and in the semi-arid areas of the Centre (Castilla y León).

In Navarra two scenarios were studied using the six-year standard rotation: *break crop*–winter wheat–winter barley–*break crop*–winter wheat–winter wheat:

a) on light soils with the break crops oilseed rape and peas (66% cereals) or oilseed rape and oats (83% cereals);
b) on deeper soils near the coast with the break crops sunflower and faba beans (66% cereals) and sunflower and oats (83% cereals), respectively.

Replacing oats by peas or faba beans, thereby reducing the percentage of cereals by 17%, improved the gross margins of the rotations by €12–18/ha (3–4%) (Figure 3). Thanks to a higher yield increase of wheat after grain legumes (+16%) compared with wheat after oats (+8%) and the additional protein crops premium, more or less the same total output could be reached as with oilseeds.

Altogether up to 4% variable costs were saved although grain legumes lead to higher costs for plant protection than oats which are a relatively extensive crop.

In Castilla y León the first crop in the four-year rotation (sunflower–winter wheat–winter barley–spring barley) was replaced by pea. On average for the years 2000–04 peas yielded 1.2 t/ha and sunflower yielded 1.0 t/ha. The selling prices, however, were much higher for sunflowers (€228/t) than for peas (€169/t). Consequently pea growers had lower market proceeds averaged over the rotation.

However, according to Spanish experts and trial results (2), peas increase the yield of following wheat by about 0.6 t/ha, whereas sunflower has no effect on following wheat yield in this semi-arid zone. Taking into consideration the additional premium for protein crops, the total average output of the pea rotation exceeded that of the sunflower rotation by nearly 7% (Figure 3).

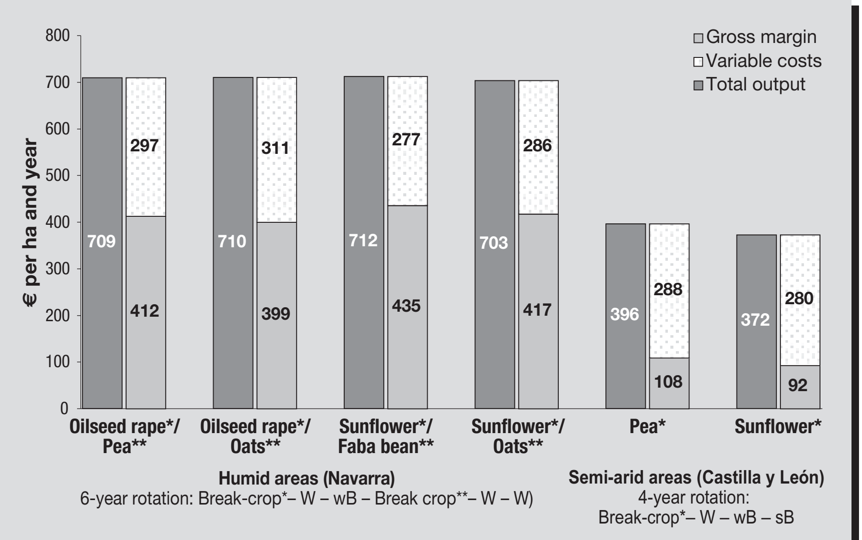
Even if the production costs were higher in the grain legume rotation, mainly because of the higher seed costs for pea, the pea rotation was highly competitive compared with the sunflower rotation: its average gross margin (€108/ha) was €16/ha (17%) higher.

High subvention for oilseeds and grain legumes in Switzerland

In Switzerland farmers may only have 15% peas in the rotation. For the region of Canton Vaud, located in the western part of the country, an eight-year rotation was studied: two sequences of oilseed rape–winter wheat–grain maize (after a phacelia catch-crop)–winter wheat. High-yielding grain maize, yielding an average of 9.3 t/ha in 2000–04, was replaced by spring peas (3.7 t/ha) and soyabeans (3.2 t/ha), resulting in 14% lower average proceeds for the rotation (€2,058/ha). Although about 11% of the production costs were saved – mainly costs for grain drying of maize – these losses could not be compensated. The cultivation of grain legumes was profitable only when the area payments were taken into consideration. Then the margin of the grain legume rotation exceeded that of the maize rotation by €30/ha (2%).

Since 2002 farmers have received an area payment of €955/ha for grain legumes, which is the same as for rapeseed. For cereals and maize nothing is paid.

It must be stressed, that in Switzerland soyabeans are usually grown by contractors. The price is nearly 50% higher than for standard peas. Between 2000 and 2004 the average price for feed peas in Canton Vaud was about €310/t, and for soyabeans €462/t.



OSR = oilseed rape, P = spring pea, SF = sunflower, FB = faba bean, W = winter wheat, wB = winter barley, sB = spring barley.

Components of the total output:
- Average yields and selling prices 2000–04:
  - Castilla y León: SF: 1.0 t/ha, €228/t; P: 1.2 t/ha, €169/t; W: 3.1 t/ha, €135/t; wB/sB: 2.8 t/ha, €123/t.
  - Navarra: OSR: 2.6 t/ha, €210/t; P: 2.5 t/ha, €156/t; Oats: 4.5 t/ha, €112/t; SF: 2.1 t/ha, €240/t; FB: 2.3 t/ha, €191/t; W: 5.1 t/ha, €134/t, wB: 4.9 t/ha, €120/t.
- Coupled CAP payments from 2006 (€15.75/t x reference yield + €55.57/ha for protein crops).

Components of the variable costs:
- Seed, fertiliser, plant protection, hail insurance, variable machine costs & contractor, calculatory interest.
- Crop management measures and prices for supplies according to crop season 2004.

Figure 3. Economic comparison of crop rotations with and without grain legumes in humid and semi-arid Spanish areas (CAP reform scenario 2006).

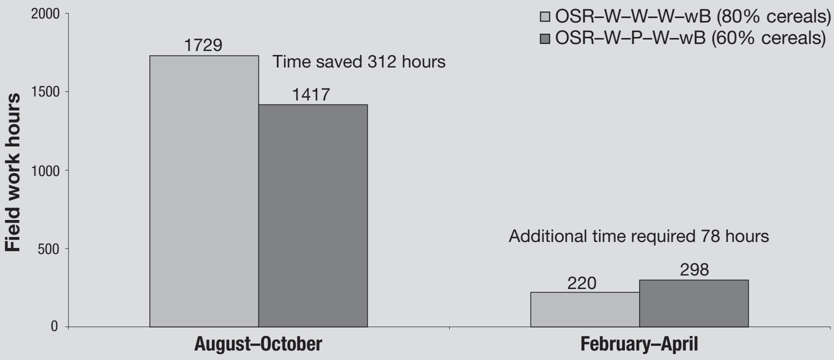
Insert 1

Common hypotheses for economic and environmental studies

In a twofold approach, the economic importance and the environmental impact of grain legumes were studied for cropping systems in Castilla y León (Central Spain), Barrois (France), Canton Vaud (Switzerland) and Saxony-Anhalt (Germany). The aim was to base the calculation of the rotation gross margins and the Life Cycle Assessment (LCA) on the same crop rotations. The data required for both approaches are largely congruent, even if the data for LCA are more extensive. Each measure needs to be defined in detail, for example, date, kind and amount of fertiliser or pesticide, the machines and equipment used, the number of field passages and the distance between different plots.

It was not possible to carry out surveys on farms to obtain the data required. Therefore cash crop farms representative of each region were described as examples. In brief, the analyses were based on the regional average yields and prices for the period 2000–04. Official statistics and market reports were the main sources to calculate the market proceeds of the crops in the rotations. The effects of the preceding crop were considered by taking into account results of rotational trials in conventional cropping systems.

To compile all input data (fertilisation, plant protection etc.) for a representative cropping year and according to up-to-date crop management recommendations, close collaboration with local extension services was necessary. Data collection, treatment and calculation were realised by a common tool based on Microsoft Excel.



OSR = oilseed rape, P = spring pea, W = winter wheat, wB = winter barley
Source: KTBL machine data collection 2003/04.

Figure 4. Labour time required in spring and autumn (including harvest) depending on rotation on a 500-ha farm in Sachsen-Anhalt.

To summarise: all the case studies show that in the short-term grain legume rotations can compete with the dominating cereal rotations in the regions. However, in addition to the rotation gross margin, labour requirements are important criteria for farmers choosing to grow grain legumes.

Better partitioning of farm labour

Cropping only winter rapeseed and winter cereals causes a labour peak in autumn (tillage, seedbed preparation and sowing of winter crops). To manage this peak, powerful and expensive mechanisation is required. That this work load can be reduced by integrating grain legumes into the rotation is shown in the following example from Saxony-Anhalt (Figure 4). When a 500-ha farm with an average plot size of 20 ha introduces spring peas into a five-year rotation of rapeseed–wheat–wheat–wheat–barley (resulting in rapeseed–wheat–pea–wheat– barley) more than 300 tractor hours can be saved between August and October. On the other hand only about 80 additional hours are required in the spring.

Machines and manpower can be used more efficiently, with the grain legume rotation allowing a greater acreage to be managed. Alternatively, the same acreage can be managed with reduced (cheaper) mechanisation.

Furthermore, it must be stressed that integrating grain legumes in the rotation allows a reduction in tillage. Minimum or non-tillage, saving labour and machine costs, may be realised also in cereal rich rotations. However, this can lead to increasing problems, for example, with straw management, grass weed regulation and certain diseases (3).

Insert 2

Methodology of economic analyses

The economic comparisons of regional crop rotations were based on one hectare. They were not implemented on the farm level, i.e. different crop or set-a-side ratios or changes in mechanisation due to restructured rotations were not taken into account. Only data on farm size and plot size were specified to determine appropriately the variable machine costs and the field working hours needed.

Total output and variable costs were taken into account to calculate the crop gross margins. Besides the market proceeds, coupled payments are part of the total output in the prospective scenario of the reform of the Common Agricultural Policy (CAP). The variable costs cover costs for seed, fertiliser, plant protection, hail insurance, grain drying, variable machine costs (maintenance, supplies) and contractor work. For a given rotation the average gross margin per hectare and year was calculated.

Grain legume rotations can be advantageous

To quantify the economic benefits of grain legumes, the entire crop rotation must be considered. The isolated comparison of crop gross margins does not reveal the monetary value of grain legumes for the following crop. Higher yields for the following crop, cost savings because of nitrogen fixation and for tillage due to improved soil structure, as well as a better management of the high demand for labour in early autumn are some of the advantages of grain legumes.

The model calculations of rotation gross margins demonstrate that diversifying tight cereal rotations with grain legumes does not cause a drop in farmers' income. On the contrary in most cases the grain legume rotation offers slightly higher gross margins than tight rotations with 75% or more cereals. At the same time the work load is managed better. ■

[1]Total output = average proceeds of selling the harvest (yield x price) + CAP payments (coupled); gross margin = total output – variable production costs (fertilisers, seed etc).

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Environmental impact of grain legumes in regional crop rotations

Impacts environnementaux des rotations de cultures incluant les légumineuses à graines

by Thomas Nemecek and GL-Pro partners*

As shown in the previous paper (1) the introduction of a grain legume in a crop rotation does not reduce the gross margin of the rotation, and may even increase it slightly in some cases. Additionally, what are the consequences for the environment of introducing grain legumes in crop rotations? This question is dealt with in this article using life cycle assessment (see Insert). Comparing a grain legume with a non-legume crop reveals some advantages of the legume (2), but does not demonstrate all of its effects on the following crops in the rotation. The impact of farming systems on the environment needs to be analysed at the rotational level (3), especially for potential problems like nitrate leaching that occur mainly in the inter-crop periods.

The same crop rotations as those used for the economic analysis (1), assessed in four study regions (Table 1), were subjected to life cycle assessment (see Insert 1 on page 19). The environmental impacts were expressed in relation to a reference unit, the so-called functional unit, and in this study two functional units were used: cultivated area (hectare per year) as a measure of the land management function and gross energy (upper heating value) of harvested products (GJ) as a measure of the productive function. The presentation of the results follows the three management areas: resource management, nutrient management and pollutant management (according to (4)).

Table 1. Overview of the crop rotations compared in the four study regions. GL = grain legumes, OSR = oilseed rape, W = winter wheat, wB = winter barley, sB = spring barley, P = spring pea, wP = winter pea, M = grain maize, SB = soyabean, SF = sunflower, (cc) = catch crop (*Phacelia*). The replaced crops are printed bold.

Region	Crop rotation 1 (without GL)	Crop rotation 2 (with GL)
Saxony-Anhalt (D)	OSR–W–**W**–W–wB	OSR–W–**P**–W–wB
Barrois (F)	OSR–W–W–wB	OSR–W–**wP**–W–wB
Canton Vaud (CH)	OSR–W–(cc)**M**–W- OSR–W–(cc)**M**–W	OSR–W–(cc)**P**–W- OSR–W–(cc)**SB**–W
Castilla y León (E)	**SF**–W–wB–sB	**P**–W–wB–sB

Lower energy demand

Including a grain legume in a crop rotation generally led to a substantially lower energy demand per cultivated area (Table 2). There are three reasons for this: a reduction in the quantity of N fertiliser (no N applied to grain legumes and less fertiliser required for the following crop (Figure 1), reduced tillage after pea in Saxony-Anhalt (Figure 1) and no energy demand for maize drying in Vaud (grain maize is replaced by a grain legume). As for the energy demand, the global warming potential and the ozone formation were also reduced in Saxony-Anhalt and Barrois, two regions with a high proportion of cereals.

Table 2. Environmental impacts per hectare times year (ha*year) for crop rotations without grain legumes (CR1) and crop rotations with grain legumes (CR2). The impacts of CR2 relative to CR1 are judged to be: ++ = very favourable, + = favourable, 0 = similar, - = unfavourable, -- = very unfavourable.

		Sachsen-Anhalt (D)			Barrois (F)			Vaud (CH)			Castilla y León (E)		
		CR1	CR2		CR1	CR2		CR1	CR2		CR1	CR2	
Resource management	Energy demand (MJ-equivalents)	24501	21066	++	22491	19921	++	31548	21856	++	10348	10749	0
	Global warming potential (kg CO_2-equivalents)	3762	3331	++	3974	3666	+	4003	3653	+	1920	2168	--
	Ozone formation (g C_2H_4-equivalents)	790	709	+	669	629	+	854	728	++	335	354	-
Nutrient management	Eutrophication (kg N-equivalents)	48.2	47.4	0	100.9	94.7	0	58.8	64.4	-	63.4	72.8	-
	Acidification (kg SO_2-equivalents)	21.4	17.7	+	44.4	36.3	+	20.4	17.5	+	9.4	9.8	0
Pollutant management	Terrestrial ecotoxicity (points)	50929	32293	++	11413	10603	0	731	862	-	387	401	0
	Aquatic ecotoxicity (points)	3846	3904	0	4701	4088	+	2708	2611	0	3332	2471	+
	Human toxicity (points)	747	636	+	990	856	+	1334	1261	0	328	342	0

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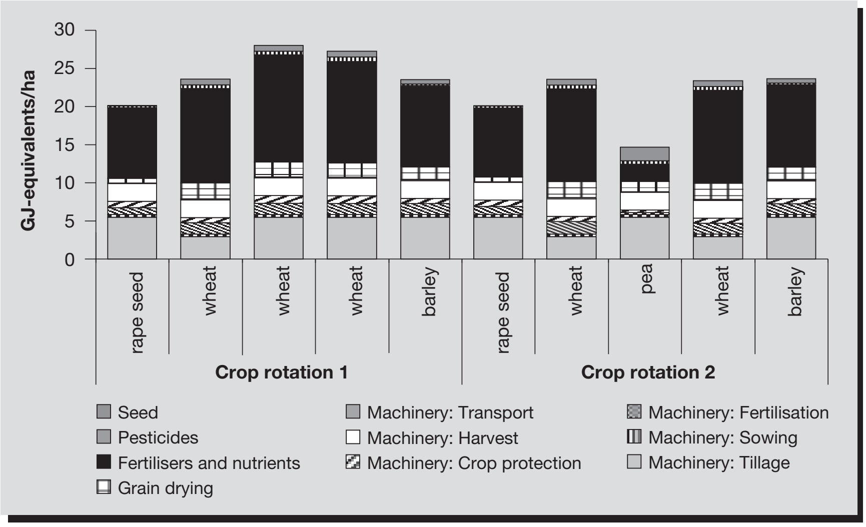

Figure 1. Demand for non-renewable energy resources for the two crop rotations in Saxony-Anhalt (D).

Insert

Life cycle assessment

Life Cycle Assessment (LCA) is a management method used to quantify and evaluate the potential impacts on the environment of a product or process during its whole life cycle. The goal is to include all relevant impacts on the environment in order to detect shifts from one environmental problem to another. An analysis of the life cycle aims to include all steps from the extraction of the raw materials to the disposal or recycling of waste. The method is defined in the ISO standards 14040 to 14043. The SALCA method (Swiss Agricultural Life Cycle Assessment, as used in (4)) includes also methods to assess impacts on soil quality and biodiversity, in addition to the usual impact categories.

The crop rotation in Spain (Castilla y León) gave less favourable results compared with the other three rotations. This is because peas replaced sunflower in Spain (Table 1), whereas grain legumes were sown instead of wheat in Germany and France or grain maize in Switzerland. In Spain, sunflower is produced extensively as an unfertilised break crop with a low yield. Replacing an extensive crop by a grain legume did not have a favourable effect on the environment. The energy demand was slightly higher with pea, due to its high seed quantity.

Sometimes higher nitrate leaching

Although nitrate leaching is generally higher after pea, crop rotation 2 (CR2) did not always have a higher eutrophication potential (Table 2), since higher nitrate losses could be compensated for by lower ammonia volatilisation. Ammonia is also responsible for the acidification potential, which was generally lower for CR2, since the total N-fertilisation, the main source of ammonia emissions, was also lower. Although the level of nitrate leaching was estimated to be higher in Barrois compared with the other regions due to the higher rainfall, CR2 performed slightly better than CR1 for the eutrophication potential, since the winter pea has a lower risk of nitrate leaching than spring pea in Saxony-Anhalt. A catch crop was included before pea in the crop rotation in Saxony-Anhalt for a sensitivity analysis (results not shown). Instead of a 4% increase in nitrate leaching a reduction of 7% resulted. In Switzerland both crop rotations included catch crops grown before the crops sown in spring (maize, pea and soyabean). In this situation the crop rotation with grain legumes had a higher eutrophication potential, which is explained by a higher risk of nitrate leaching.

Advantageous pollutant management

In terms of pollutant management (ecotoxicity and human toxicity potentials), equal or lower impacts were observed for CR2 compared with CR1. For intensive crop rotations rich in cereals (Germany and France), more favourable results were obtained for CR2 because a break crop reduced the number of pesticide treatments required for the cereals. Only for the crop rotation in Switzerland was terrestrial ecotoxicity increased, because insecticide treatment was required for pea but not for maize. However, it should be noted that the terrestrial ecotoxicity potential is much lower in Vaud than in Saxony-Anhalt or Barrois. The results depended heavily on the choice of pesticide active ingredients.

No effect on soil quality and biodiversity

The potential impacts on soil quality and biodiversity were only assessed for Vaud. Soil quality indicators were not changed significantly by the inclusion of grain legumes, but the Swiss crop rotation is already quite diverse.

Table 3. Environmental impacts per GJ gross energy of the harvested products for crop rotations without grain legumes (CR1) and with grain legumes (CR2). The impacts of CR2 relative to CR1 are judged to be: ++ = very favourable, + = favourable, 0 = similar, - = unfavourable, -- = very unfavourable.

		Sachsen-Anhalt (D)			Barrois (F)			Vaud (CH)			Castilla y León (E)		
		CR1	CR2		CR1	CR2		CR1	CR2		CR1	CR2	
Resource management	Energy demand (MJ-equivalents)	227	210	+	233	217	+	294	251	++	256	268	-
	Global warming potential (kg CO_2-equivalents)	35	33	+	41	40	0	37	42	--	47	54	--
	Ozone formation (g C_2H_4-equivalents)	7.3	7.1	0	6.9	6.8	0	8.0	8.4	-	8.3	8.8	-
Nutrient management	Eutrophication (g N-equivalents)	446	471	0	1046	1030	0	547	740	--	1568	1817	-
	Acidification (g SO_2-equivalents)	199	176	+	460	395	+	190	201	0	232	244	0
Pollutant management	Terrestrial ecotoxicity (points)	472	321	++	118	115	0	7	10	--	10	10	0
	Aquatic ecotoxicity (points)	36	39	0	49	44	0	25	30	-	82	62	+
	Human toxicity (points)	6.9	6.3	0	10.3	9.3	0	12.4	14.5	-	8.1	8.5	0
	Gross energy production GJ/(ha*year)	108	101		97	92		107	87		40	40	

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Biodiversity was slightly higher for CR2 compared with CR1 (7.3 versus 7.1 biodiversity points) because maize was replaced by a grain legume. Maize had a particularly low biodiversity potential because of the application of unselective herbicides. Replacing another crop would not have had the same effect.

Less favourable results for the productive function

When the environmental impacts were evaluated in relation to the second chosen functional unit (gross energy of the harvested products in GJ as a measure of the productive function, Table 3), the results for CR2 relative to CR1 were less favourable than when the evaluation was done using cultivated area (a measure of the land management function) as the functional unit. This was because the energy production was lower with grain legumes than with wheat or grain maize. The difference in gross energy production was especially large in Switzerland, where the highly productive grain maize was replaced in the rotation by pea. Despite the lower energy production with grain legumes, the energy efficiency (energy demand per GJ produced) is better with the exception of Spain.

Positive effects in intensive rotations

From these four case studies in Germany, France, Switzerland and Spain it can be concluded that the introduction of grain legumes in intensive crop rotations with a high proportion of cereals and intensive N-fertilisation is likely to reduce energy use, global warming potential, ozone formation and acidification as well as eco- and human toxicity per unit of cultivated area. Nitrate leaching tends to be higher in general, but can in many cases be reduced by including catch crops or sowing winter grain legumes, where possible. No differences were found for soil quality and biodiversity. In low-input crop rotations like the one in Spain, no significant changes in environmental impacts are to be expected. Due to the lower yields of grain legumes compared with cereals, the advantages of grain legumes are smaller when considered per GJ gross energy of the harvested products.

Therefore introducing grain legumes in European crop rotations offers interesting options to reduce environmental burdens, especially in a context of depleted fossil energy resources. ■

This research was supported by the European Commission (grant no QLK5-CT-2002-02418) and by the Swiss State Secretariat for Education and Research.

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Grain legumes are shown to contribute to a sustainable and environment-friendly European agriculture

by Julia-Sophie von RICHTHOFEN, Hubert PAHL and Thomas NEMECEK

The preceding value of grain legumes is well known by European farmers. This was demonstrated more clearly by a survey of more than 500 grain legume non-producers carried out within the scope of the Concerted Action GL-Pro (European extension network for the development of grain legume production in the EU, QLK-CT-2002-02418). Farmers consider grain legumes to be good break crops, resulting in an increase in the yield of the following crop. However, this contribution to the profitability of the following crop is not credited to the grain legume crop's account. Grain legumes are therefore often seen as less profitable compared with arable crops like oilseed rape or wheat, because farmers make cropping decisions using the crop gross margin or even the crop proceeds.

However, from an economic viewpoint the numerous preceding effects of grain legumes can only be assessed correctly, when the whole rotation is taken into account. Case studies to calculate the average gross margins per hectare and per year of rotations with and without grain legumes were made in regions of France, Germany, Spain and Switzerland. The results show that diversified rotations with grain legumes compare well with tight cereal rotations. If grain legumes are integrated in cropping systems with 75% and more cereals, the rotation margin is actually increased. In addition the work-load in early autumn can be reduced.

Furthermore, the environmental consequences of diversifying rotations with grain legumes were studied by means of Life Cycle Assessment. In intensive cropping systems, with a high proportion of cereals and high N-fertiliser input, the incorporation of grain legumes has especially beneficial effects on the environment. The use of fossil energy resources is reduced and so is the emission of greenhouse gases. In addition, ammonia volatilisation causing acidification is lower in grain legume rotations. These benefits result primarily from the lower level of industrial N-fertiliser use because of the symbiotic fixation of atmospheric nitrogen by the grain legume crop. The risk of nitrate leaching, however, is often increased by the inclusion of a grain legume crop. It can be reduced by efficient catch-crop management, inter-cropping or sowing winter grain legumes, where possible.

With respect to pollutant management, introducing grain legumes in the crop rotation contributes to lower eco and human toxicity. Less herbicides and fungicides are used because grass weed infestation and certain diseases in cereal-rich rotations are reduced by the break-crop effect of grain legumes.

Economic and environmental results are largely congruent: introducing grain legumes in intensive crop rotations with a high proportion of cereals leads to a slightly higher gross margin and simultaneously to more favourable effects on the environment. ■