Legume Futures

Legume-supported cropping systems for Europe

Legume Futures Report 4.5

Impacts of legume-related policy scenarios

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Legume Futures

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FOREWORD

Legume Futures, "Legume-supported crop rotations for Europe", is an international research project funded under the European FP7 programme. It has 20 partners in 13 countries. The project aims to develop and assess legume-supported cropping systems that improve the economic and environmental performance of farming in Europe.

This report is part of the socio-economic research in the project which aimed to assess the economic effect of including legumes in farming systems both in relation to the internal (economic) effects for the farmer and the external effects, especially on the environment. The objective of the research reported is to show what impact various possible policies that impact on the use of legume might have on economic performance, public finances and on the environment. In addition, some scenarios are presented of developments that might occur due to policies not specifically aimed at promoting legumes, or that may come about autonomously.

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1 December 2013

1. INTRODUCTION

The challenge of increasing the use of legumes in cropping systems can briefly be described as a contradiction between, on the one hand, the considerable environmental benefits of these crops and, on the other, the decline in the production of legumes in Europe while their consumption is increasing. The underlying reasons for this must be sought in the economic domain: the decreasing production of legumes is due to the lower and more uncertain revenue they bring to farmers, compared to crops that bring higher and more reliable revenues; while the increasing consumption is related to our demand for animal products, requiring large quantities of high quality plant protein, particularly for pigs and poultry.

This research looks at the prospects for mitigating this problem. We may look for such possibilities in three directions:

- research and extension to arrive at improved and profitable farming systems which incorporate legumes;
- autonomous developments in the economy and in the environment, which may make legumes more attractive to European farmers; and
- policies, notably such as can be part of the Common Agricultural Policy of the EU.

This report examines the second and third approach, taking into account such knowledge as has already been generated on improved legume-growing and its economics.

The effects of both autonomous developments and policies can be simulated in the shape of scenarios: imagined situations in which a policy or a supposed trend occurs, as compared to a counterfactual in which it does not. In this study, the model CAPRI is used to calculate the impact of such scenarios on a number of important economic and environmental variables at regional level.

This report first provides a description of the scenarios applied (first autonomous trends, then potential policies). This is preceded by a general description of the economic aspects of legume-growing, providing the basic information to be fed into the model through the scenarios. The scenario narratives are followed by a description of the model CAPRI. Next, the outcomes of the various simulations are presented and discussed, and the final chapter, naturally, offers some conclusions based on the exercise as a whole.

2. THE ECONOMICS OF INCLUDING LEGUMES IN CROPPING SYSTEMS

This chapter documents the knowledge on legumes which is needed for the model described in Chapter 4. This is economics in the broad sense: those variables which lead to costs and benefits for farmers as well as for society as a whole, and which therefore ought to be incorporated into a social cost-benefit analysis in order to help in choosing between policy alternatives. These naturally include aspects of the environmental impact. The research identifies the variables needed for a cost-benefit assessment; it also attempts to quantify them, for the present situation (this chapter) and under different possible scenarios (Chapter 5).

The data used for this chapter are taken from results achieved by other work packages in the Legume Futures project. Much of the information is contained in the report on legumes produced for the European Parliament earlier in 2013,[1] which is quoted here extensively.

2.1 History and policies

Legumes (defined as cultivated plants of the *Fabaceae* family) have long been grown as the primary source of protein for human nutrition. Animal protein from fish, meat, eggs and milk was available but mostly scarcer and thus more expensive. In many parts of Africa, farmers still grow beans or peas as their second most important crop, beside staple crops such as maize or cassava. Livestock was grazed mostly on land unsuitable for crops, or on fallow. For millennia, a combination of cereals and pulses has formed the basis of a healthy diet in many cultures in Europe, Asia, Africa and Latin America. The soil-enhancing properties of pulses and other legumes were also well known.

The growth of prosperity has profoundly altered our diets and therewith our farming systems. In Europe and elsewhere, human consumption of pulses has declined and consumption of animal products has increased. Livestock products have become cheaper (although are a more expensive source of protein than plant products) by intensification of production, including intensification of feeding. Non-ruminant animals such as pigs and poultry in particular need digestible protein-rich feed.

Thus, the expansion of livestock production in richer countries has led to a considerable increase in the consumption of legumes, even though direct human consumption has declined. Most of this increase has been in the form of soybeans and soybean meal (the by-product of soya oil extraction). Nearly all of this soya is imported: in 2010, the 28

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[1] Bues, A., S. Preiβel, M. Reckling, P. Zander, T. Kuhlman, K. Topp, C. Watson, K. Lindström, F.L. Stoddard & D. Murphy-Bokern, 2013. The environmental role of legumes in the new Common Agricultural Policy. European Parliament, Brussels, Policy Department B: Structural and Cohesion Policies, document IP/B/AGRI/IC/2012-067.

member states of the EU imported 15 million tonnes of soybeans and 30 million tonnes of soybean meal, together the soybean equivalent of 53 m tonnes.[2] This is because (a) soybeans are probably the best-quality source of vegetable protein on the market, and (b) the climate in most European countries is more suited for growing cereals than soybeans. Stockfeed manufacturers in Europe became aware of the high quality of soybean meal in the early 20th century.[3] However, it was the Dillon Round of GATT agreements (1962) that really launched large-scale imports of soya into Europe: the European Economic Community (precursor of the EU) had insisted on high import tariffs for cereals in order to protect its wheat farmers from foreign competition. In compensation, it had accepted the tariff-free import of grain substitutes – mostly soybeans and cassava. It was this opening-up of the European market to cheap imports of stockfeed that made the expansion of intensive livestock-keeping possible. It led to significant gains for European livestock farmers and to cheap products for European consumers. The cost has been large nitrogen surpluses (leading to environmental pollution) in consuming countries and environmental degradation in producing ones – particularly in Latin America,[4] where production expanded from the late 1960s onwards, in response to growing demand from Europe.[5] World production of soybeans has increased tenfold in the last 50 years, to over 260 million tonnes in 2012/13.

It would be very difficult for European arable farmers to produce sufficient amounts of pulse crop to substitute the current flow of soy imports: on the basis of average soybean yields in the EU (2.8 tons.ha^{-1} in 2011), 19 m hectares would be required, out of a total of 104 m hectares of arable land. However, since large parts of Europe are not suitable for growing soya, most of the protein would have to be provided by other pulses. Although these can give yields similar to soy, their protein concentration is lower. Growing pulses for this purpose would probably require an area of 25-30 m hectares.

However, Europe's current dependence on imported proteins is not primarily caused by its inability to grow enough by itself: the production of especially grain legumes (pulses and soybean) is in long-term decline, from 4.7% of all arable land in 1961 to 1.9% in 2011.[6] This is due to:

a) competition from low-cost legume producers in other countries, mostly from North and South America, as mentioned; this has been aided by tariff-free imports;

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[2] Figures calculated from FAOStat data.

[3] Prodöhl, I., 2010. A Miracle Bean: How Soy Conquered the West. Bulletin of the GHI 46 111-129. German Historical Institute, Washington, DC.

[4] Fearnside, P.M., 2001. Soybean cultivation as a threat to the environment in Brazil. Environ. Conserv. 28(1), 23-38.

[5] Shurtleff, W., Aoyagi, A., 2007. History of World Soybean Production and Trade. Soyinfo Center, Lafayette (Cal.).

[6] Bues, op. cit., 27-28.

b) competition from wheat and other cereals for land in Europe; in the past this has been aided by market support for wheat producers.

c) competition from nitrogen fertilizer as an alternative way to maintain soil nitrogen levels; this has been aided by the availability of cheap fossil energy for manufacturing nitrogen fertilizer.

European policymakers noticed early on that the support for wheat and the absence of support for pulses led to changes in cropping patterns, and that these changes would negatively affect the supply of protein crop commodity.[7] Therefore, a subsidy for so-called protein crops (faba bean, pea and sweet lupin) was introduced in 1981. In the 1992 MacSharry reform, this subsidy was replaced by an area-based premium. By the time it was discontinued in 2006, it could amount to several hundred euros per hectare. The abolition of this premium led to a steep decline in areas under grain legumes, even though until 2012 some countries still paid a smaller premium for legumes. Figure 1 shows how these vicissitudes of policy have affected the area of legume cultivation: farmers clearly react to subsidies, but these have not been able to fully compensate for the long-term downward trend. Moreover, in recent years the premiums have been too small to make much impact.

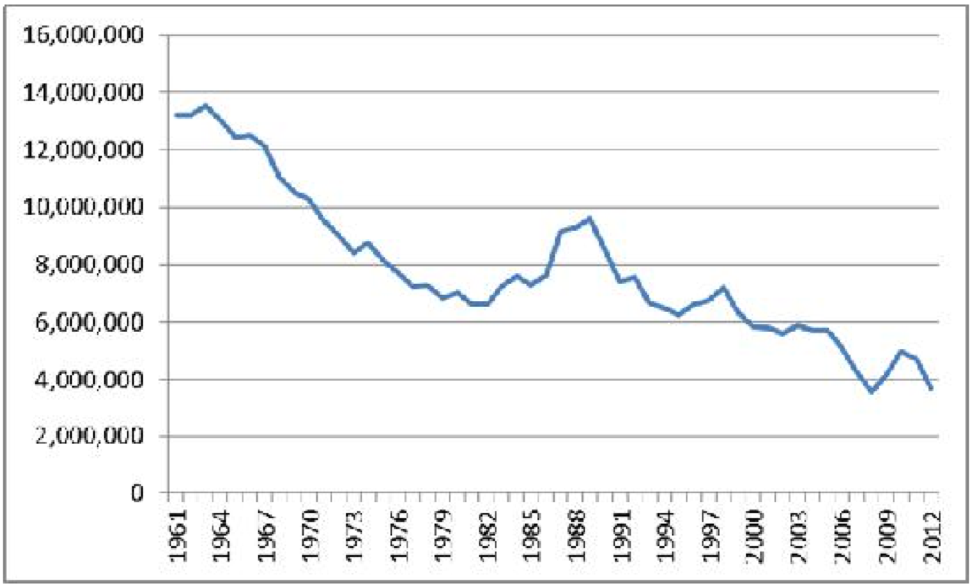

Figure 1. Evolution of area cultivated in legumes, EU-28[8]
Source: FAOStat

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[7] Bowler, I.R., 1985: Agriculture Under the Common Agricultural Policy: A Geography. Manchester University Press, pp. 51-52.

[8] excluding the Baltic states, Slovenia and Croatia before 1992, and the former German Democratic Republic before 1991; not including forage legumes.

2.2 Benefits and costs[9]

2.2.1 Farm-level costs and benefits: grain legumes

The average gross margin of grain legumes in a number of European countries and regions for which figures are known has been calculated at €240 per hectare, compared to €544 for wheat. Moreover, the yields of pulses tend to be more risky than the yields of cereals.[10] Also, cereal yields have increased faster than those for legumes in recent decades,[11] probably at least in part due to the higher support level for cereals.

However, these figures include only the immediate yield of the legume crop itself, not the beneficial effect it has on succeeding crops. If we include this pre-crop effect, grain legumes are still less profitable than competing crops, but the difference is much smaller; and in some cases rotation systems with legumes produce higher gross margins than those without.[12] It is to be noted that this pre-crop benefit will be greatest in regions where at present the proportion of cereals in arable land is high, such as Poland, western Germany and northern Italy.

On the other hand, the higher yield variability is usually quoted as a disadvantage of legume crops. This variability (expressed as the mean divided by the variance) is in peas, for instance, typically 50-60% higher than for wheat.[13] Also, the production of legume crops are beneficial for society because of the environmental externalities of the legume crops.

2.2.2 Farm-level costs and benefits: forage legumes

Apart from grain legumes (i.e. those legume crops grown for their seeds) we must also consider forage legumes: plants grazed by livestock, cut and carried to livestock, or preserved as silage for feeding later. These include, for instance, various types of clover, alfalfa/lucerne and vetches. They may be sown into grassland or cultivated in pure stands for silage. Forage legumes have also declined, although exact figures are difficult to give – particularly for mixed stands of grasses and legumes. They have been replaced by fertilised forage crops (pure grasses and silage maize), supplemented by imported soya.[14]

A comparison between pure grass with nitrogen fertiliser and a mix of grass and white clover in Ireland shows that the former indeed produces a higher yield than the latter. The productivity of grass-clover swards in terms of dry matter was found to be 10%

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[9] These are treated in detail in Deliverable 4.6.

[10] Bues, op. cit., 87-88.

[11] Bues, op. cit., 29.

[12] Bues, op. cit., 89.

[13] Bues, op. cit., 88.

[14] Bues, op. cit., 82.

lower than N-fertilised grass swards in the Netherlands and 8% lower in Ireland. However, the energy content of the grass-clover sward is also 4% lower, so that effect has to be added. As a result, both stock density and milk yield are lower on grass-clover mixtures: Schils[15] reports 15% lower milk production from such mixes in the Netherlands, compared to N-fertilised grass. However, the difference in net results has become smaller in recent years, due to the rising price of fertiliser and the decline in the milk price.[16] As a result, grass-clover swards are not necessarily less profitable than fertilised pure grass.

These results refer to permanent pastures. They are different for temporary leys, where legumes can produce additional benefits by saving fertiliser on the crop produced after the grass sward.[17] The economic performance of such swards compared to pure grass is varied: from slightly negative to significantly positive.[18]

The yield of grass-clover mixtures depends on the type of grazing and on climate.[19] For example, Oyen and Pestalozzi[20] found that continuous grazing leads to more abundant growth of clover compared to rotational grazing. However, in warmer environments such as the Po Valley, the opposite is the case.[21]

2.2.3 Environmental costs and benefits

The principal environmental effects of legumes are the following:

(1) First of all, since they stimulate biological nitrogen fixation, legumes reduce the need for N fertiliser both for themselves and for the succeeding crop. If grain legumes are grown instead of wheat, the reduction in fertiliser nitrogen used is normally 100-200 kg $N.ha^{-1}.year^{-1}$. The effect on the succeeding crop can save another 10-30 kg.[22] On grassland, a high proportion of clover in grass-based swards can save 150-200 kg $N.ha^{-1}.year^{-1}$, depending on management[23] Manufacturing N fertiliser requires large amounts of energy, so substituting biological nitrogen fixation reduces industrial greenhouse gas emissions. The greenhouse effect of manufacturing, packaging and transporting

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[15] Schils, R.L.M., 2002. White clover utilization on farms in the Netherlands. Wageningen University, Ph.D. dissertation.

[16] Humphreys, J., Mihailescu E., Casey, A., 2012. An economic comparison of systems of dairy production base on N-fertilized grass and grass-white clover grassland in a moist maritime environment. Grass Forage Sci., 67(4), 519-525.

[17] Bues, op. cit., 93.

[18] Ibid.

[19] Reyneri, A., Grignani, C., Cavallero, A., 1996. The role of white clover in the south European grazing system: The Po Plain situation. REU Technical Series, 42, 19-27.

[20] 1994, cited in Reyneri, op. cit.

[21] Cavallero et al, 1993, cited in Reyneri, op. cit.

[22] Bues, op. cit., 38.

[23] James Humphreys, personal communication.

nitrogen fertilizer is highly variable, depending on the technology used, the type of fertiliser, and the energy source. It may vary from 2-12 kg CO_2 equivalent per kg of nitrogen.[24] Snyder et al.[25] use a standard of 4.51, while Kool et al.[26] arrive at 5.62 for Western Europe and 6.87 for Eastern Europe. As a rough standard, we propose to use 6 kg CO_2 equivalent per kg N.

(2) Not all of the N input to crops is absorbed into the crop itself, so agriculture causes N surpluses which lead to in increased emissions of nitrous oxide (N_2O) and nitrates. The former is a potent greenhouse gas emitted into the atmosphere, the latter a source of eutrophication in surface water. The literature indicates that legume crops produce little or no emissions of nitrous oxide when growing, although there will be some emissions from crop residues in the next year.[27] The emission factor for N_2O from crops fertilised with synthetic N fertiliser are estimated by the IPCC at 1.25%, which is equivalent to 20 grams of N_2O for each kg of N applied, or 6 kg $CO_{2e.}$[28] Therefore these emissions are of the same order of magnitude as the greenhouse effect from fertilizer production. This means that the production of grain legumes may lead to a reduction of roughly 1-2.5 t $CO_2.ha^{-1}$ in the year of production and another 120 kg in the following year under a different crop.

(3) The digestive system of livestock also produces methane, another greenhouse gas. In a grass-clover mixture, this emission is the same as in N-fertilised grass.[29] Taking all greenhouse gas emissions in grassland systems together, they are up to 23% lower per kg of milk in grass-clover mixtures, at least in Ireland.[30] However, Schils et al.[31] found only 11% reduction in emissions, because he counts with more frequent ploughing of grass-clover mixes, leading to lower carbon sequestration and higher N losses.

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[24] Wood, S., Cowie, A., 2004. A Review of Greenhouse Gas Emission Factors for Fertiliser Production. State Forests of New South Wales, West Pennant Hills, NSW (Aus.).

[25] Snyder C.S., Bruulsema, T.W., Jensen, T.L., Fixen, P.E., 2009. Review of greenhouse gas emissions from crop production systems and fertilizer management effects. Agr. Ecosyst. Environ., 133, 247-266.

[26] Kool, A., Marinussen, M., Blonk, H., 2012. LCI data for the calculation tool Feedprint for greenhouse gas emissions of feed production and utilization: GHG Emissions of N, P and K fertilizer production. Blonk Consultants, Gouda (Netherlands).

[27] Bues, op. cit., 39.

[28] IPCC. 2007. Climate Change 2007: Synthesis Report. Intergovernmental Panel on Climate Change, Geneva (available at www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html). Also: Kindred, D., Berry, P., Burch, O., Sylvester-Bradley, R., 2008. Effects of nitrogen fertiliser use on greenhouse gas emissions and land use change. Aspect. Appl. Biol., 88, 53-56;
cf. also Bouwman, A.F., 1996. Direct emission of nitrous oxide from agricultural soils. Nutrient Cycling in Agro-Ecosystems, 46, 53-70.

[29] Yan, M.J., Humphreys, J., Holden, N.M., 2012. The carbon footprint of pasture-based milk production: Can white clover make a difference? J. Dairy Sci., 96(2), 857-65.

[30] Yan, op. cit.

[31] 2005, cited by Yan, op.cit.

(4) In general, total greenhouse gas emissions in grassland-clover are lower than in fertilised grassland systems.[32] Yet, the higher protein content of white clover can lead to an increase of urinary N output leading to a higher emissions of NH_3 and N_2O.[33]

(5) Nitrate leaching (a major source of eutrophication) from legumes is lower in the year of cultivation, but in the year of the succeeding crop there will be excess nitrate from the preceding legume crop as well as from the fertilizer applied. In general, including legumes in a rotation system probably makes little difference to nitrate leaching. Schils[34] arrives at a lower overall nitrogen surplus for his grass-clover sward as compared with grass alone, but this is due to the lower stock density (and therefore lower milk production), not due to the effect of the legume as such.

(6) Legumes also contribute to soil organic carbon, an important resource for improving soil structure and composition. Increasing soil organic carbon is also a form of carbon sequestration and therefore reduces greenhouse gas emissions. For grain legumes, this effect is 350 $kg.ha^{-1}.yr^{-1}$ even when the straw is not ploughed back into the soil, compared to a net loss for most other crops (wheat -700 kg, silage maize -1,350 kg, potatoes -1,800 kg). A grass-clover mixture has a positive balance of 2,100 $kg.ha^{-1}.yr^{-1}$ and lucerne 1,800 kg, as compared to 1,050 kg for regular grassland.[35] Yet, the effect does not always occur, depending on the particular crops and the climatic zone.[36]

(7) Including grain legumes into arable crop rotation systems can lead to a reduction in the use of pesticides. This is not an effect of the legume crop itself (which is as susceptible to pests as any other crop), but of the rotation as such. Other 'break' crops also have this effect.[37]

(8) There is some impact on biodiversity: legume crops tend to promote the population of bees, particularly in northwestern Europe, because they flower at a favourable time. Furthermore, a positive effect on other invertebrates has been noted from perennial forage legumes such as lucerne, bird's foot trefoil, and sainfoin.[38]

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[32] Ledgard, S., Schils, R., Eriksen, J., Luo, J., 2009. Environmental impacts of grazed clover/grass pastures. Irish J. Agr. Food Res., 48, 209-226;
Clark, D.A., Harris, S.L., 1996. White clover or nitrogen fertiliser for dairying? Agronomy Society of New Zealand, Special Publication No. 11/ Grassland Research and Practice Series No. 6, 107-114.

[33] Novak, S.M., Fiorelli, J.L., 2010. Greenhouse gases and ammonia emissions from organic mixed crop-dairy systems: a critical review of mitigation options. Agron. Sustain. Dev., 30, 215-236.

[34] Schils, R.L.M., 2002. White clover utilization on farms in the Netherlands. Wageningen University, Ph.D. dissertation.

[35] Bues, op. cit., 40.

[36] Ibid.

[37] Bues, op. cit., 39.

[38] Bues, op. cit., 39-40.

(9) Finally, legumes can take up insoluble phosphate from the soil and make it soluble, thus reducing the need for phosphate fertilizer. However, this effect is rarely taken into account in fertilizer recommendations.[39]

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[39] Bues, op. cit., 41.

3. SCENARIOS

This chapter describes possible future developments which may improve the economic case for legumes. Since, as we saw in the previous chapter, legume cultivation is insufficiently attractive to farmers – insufficient, that is to reverse recent trends – policy targeting to make legumes more attractive relative to other crops are needed. These policies can be specifically aimed at promoting legumes, or aimed at other policy objectives where legumes promotion is a by-product. We have therefore constructed four policy scenarios and one scenario built on a potential autonomous development, namely disruptions that could arise in European soy imports. In addition, we have built a reference scenario in order to serve as counterfactual for the other five. In this chapter these scenarios are briefly described. The results of modelling them in CAPRI are presented in Chapter 5.

3.1 Reference scenario

To show the impact of a particular scenario, we must compare its outcome with a counterfactual, i.e. where the events simulated under that scenario do not take place. The proper counterfactual is what will happen if present trends continue, rather than the present situation. Hence, for the reference scenario we let present trends continue without any change in policy. It is not to be regarded as a forecast of what is most likely to happen, but only a projection of what will happen under certain circumstances.

3.2 Increasing worldwide use of genetically modified soya

As indicated in section 2.1, Europe largely depends on imported soya for protein supplementation in the production of meat, dairy and eggs. The EU (excluding Croatia) imports 37 million tonnes of soybeans (average over 2007-12, including soy meal expressed in soybean equivalence). It produces less than 1 million tonnes. Nearly all soya imports come from a few South American countries (mostly Brazil and Argentina, some from Paraguay and Uruguay) and from the United States. Canada and the Ukraine are minor suppliers. There are other countries that produce significant amounts of soya (e.g. China), but they are net importers.

Most of this soya is genetically modified: 91% in the US, 99% in Argentina, 71% in Brazil and 85% in Paraguay.[40] GM feed is not prohibited in the EU (except in organic farming), but it is strictly regulated: each new variety has to be approved, and this process is time-consuming. Furthermore, GM food and feed must be clearly labelled as such, and individual member states may ban varieties that have been approved by the European Commission. Only two GM crops have so far been approved for cultivation within the

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[40] Nowicki, op. cit., p. 17.

EU, a maize variety and an industrial potato. The risk of this complex approval process is that as new GM varieties of soya are developed and approved in producing countries, there will be a delay before they are approved in the EU – or they may fail to be approved at all. If those same varieties are applied widely in a producing country, it might become difficult to produce enough of the varieties admissible to the EU. This could lead to a disruption in the supply of soya – the more so since there are only a few supplying countries.

Moreover, there is a policy of zero tolerance for the presence of unauthorized GMO varieties. Thus, if trace quantities of a such a variety are found in a shipment, the entire shipment will be condemned. This presents a major risk for traders, which of course will be reflected in the price. The main issue is whether authorized and unauthorized varieties can remain segregated not only in the exporting countries, but throughout the supply chain: anywhere along the line of supply, i.e. on the farm, in storage, in processing facilities and in transport, supplies from different origins can be mixed. Even on seed-producing farms, inadvertent cross-pollination between different varieties can occur. If undesired commingling of varieties does occur, tests must be carried out in order to establish where a particular quantity is pure and therefore suitable for shipping to the EU. The costs of such segregation tend to rise exponentially with the desired level of purity. Nowicki et al. conclude that segregation programmes are likely to prove not only costly, but unsuccessful.[41] This situation steadily worsens because of the rapid increase in the number of GMO varieties.

This generates an extra cost to traders, which is reflected in the price paid for feed by livestock producers. Since the production of GM soya in exporting countries is increasing continuously, the premium European producers pay over producers in other parts of the world may become prohibitively high.[42] This presents an opportunity for the production of legumes in Europe.

In the scenario it is assumed that the present situation will continue, in that (a) more and more GMO varieties will go into production; (b) the EU approval of these varieties will lag increasingly behind their coming on stream; (c) there will be no inexpensive means of testing for low-level presence of unapproved varieties; and (d) zero tolerance of such low-level presence will be maintained.

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[41] Op. cit., p. 65.

[42] Nowicki, P., Aramyan, L., Baltussen, W., Dvortsin, L., Jongeneel, R., Pérez Domínguez, I., Wagenberg, C. van, Kalaitzandonakes, N., Kaufman, J., Miller, D., Franke, L., Meerbeek, B., 2010. Study on the Implications of Asynchronous GMO Approvals for EU Imports of Animal Feed Products, Final Report. Agricultural Economics Research Institute, The Hague / Economics and Management of Agro-biotechnology Center, University of Missouri / Plant Research Institute, Wageningen.

3.3 Premium per hectare for grain legumes

The most straightforward way to promote legume cultivation would be to pay a premium, in order to compensate farmers for the lower profit they obtain from these crops. Our first policy scenario therefore simulates a situation where a payment per hectare for growing grain legumes is introduced. Such a payment would be similar to the protein-crop premium which existed until recently in the CAP. Hence, it would not be linked to production, as the former coupled payments were. In the model CAPRI legumes are represented by pulses (peas and faba beans) and soybean.

The two previous scenarios can be seen both as autonomous developments or as the consequence of policy, but the policy as such is not directly concerned with promoting legume cultivation in Europe. The sections that follow discuss potential policies aimed specifically at increasing legume production. The most obvious such policy would be to pay farmers a premium for growing legumes. This is not, strictly speaking, a coupled payment, because it is linked to the area cultivated, not to the amount produced.

The payment is such that the total premium paid in any one NUTS2 region does not exceed 2% of the direct farm payment budget from Pillar 1 of the CAP. In regions with a very limited acreage of grain legumes and relatively high direct farm payment budgets, this could lead to a very high payment per hectare. To avoid this, we have assumed that the legume premium per hectare should also not exceed the national average direct farm payment per hectare. Given these assumptions and the total acreage under legumes in the reference, the necessary budget in the reference situation can be calculated.

The budget for legume payments goes at the expense of the direct farm payments. Hence, total Pillar I payments will decrease in regions with no legumes production, while it will increase in regions with relatively high share of legumes in the total cropping plan.

After the introduction of the premium, the grain legumes become relatively more profitable and more land will be allocated to them. This could provoke an overshooting of the initial regional budget. It is assumed that the premium per hectare will be reduced proportionally with the increase of the acreage of legumes per region.

3.4 Legumes included in Ecological Focus Areas

Another possibility is to include legumes in the Ecological Focus Areas (EFA) which will come into being as a result of the CAP reform, effective from 2014. They are intended as a contribution to making European agriculture more environmentally sustainable. 7% of arable land and land under permanent crops or horticulture must be EFA land (5% for the first few years). This is a condition for obtaining 30% of the direct farm payment, to which farmers are entitled under Pillar 1 of the CAP. There are several options which farmers can use to provide the EFA. All aim to increase environmental benefits from land management: buffer strips, fallow with semi-natural vegetation, maintaining landscape elements, and various forms of environment-friendly practices. One of these could be growing grain legumes.

In this scenario, we suppose that, in view of the environmental benefits of legumes, farmers can opt to grow legumes (pulses or soybean) as one of the ways to fulfil EFA requirements. Other ways are to leave the land under fallow or semi-natural vegetation, or to use it for landscape elements such as hedgerows or ponds.[43] In CAPRI, the EFA requirement can be modelled as a restriction:

- Per NUTS2 region it is assumed that 7% of all cropland, including fallow land, voluntary set-aside, vegetables, and permanent crops needs to be appointed as EFA.
- To fulfil this requirement the regional farmer can include the following CAPRI activities in a cropping plan:
    - Fallow land (uncropped)
    - Set-aside
    - Pulses
    - Soybean
- Depending on the levels of the above activities, the part of the EFA that is not filled can be calculated (fraction).
- This fraction is multiplied with the total acreage of agricultural land to get an estimation of the total acreage not complying with the EFA requirement.
- In the objective function of CAPRI, the total acreage not complying with the EFA requirement is multiplied by 30% of the average regional Pillar 1 payment per ha and subtracted from total agricultural income. In this way, the farmer has an incentive to comply with the EFA requirement.

3.5 Incentives for a shift in consumption from meat towards vegetable protein

In this scenario we assume that an extra tax is levied on meat consumption and an equivalent subsidy is introduced for human consumption of vegetable protein, such that total meat consumption in the EU-27 decreases with 2.5% compared to the reference. The animal protein is substituted to that extent by vegetable protein.

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[43] Such landscape elements cannot be modelled in CAPRI, as they are not included in the utilized agricultural area (UAA). The EFA regulation applies to farms with a total area (excluding permanent grassland) of more than 15 hectares (EU Memo/13/621 of 26 June 2013). In many cases, such farms will already have 7% of their total area under semi-natural vegetation, but we do not have the data to specify this. The model therefore assumes that a farmer who does not already have 7% of his land under fallow or set-aside must take the necessary measures – or, to be precise, a NUTS2 region must take such measures.

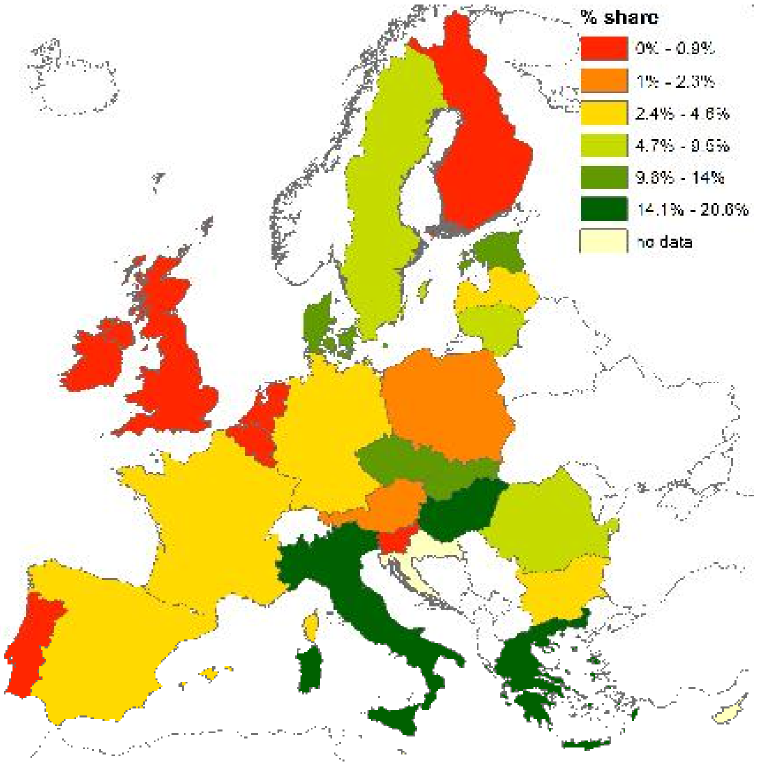
In CAPRI this is implemented as follows:

- The margin between the consumer price and the producer price of meat products (beef, pork, sheep and goats and poultry meat) and pulses is shocked;
- We assume an EU-27 average shock in the margin equal for all meat products and all member states. The average shock corresponds to a decrease of 2.5% of all meat consumption in the EU-27 (beef, pork, mutton, goat and poultry);
- We do the same for pulses, such that the consumption of pulses in the EU-27 increases with 2% of the total meat consumption. As pulses contain more protein, this way the protein balance is largely unchanged;
- An iterative procedure is applied until the increase in consumption of protein from pulses corresponds to the decrease in protein consumption from meat in the EU27 as a whole.

3.6 Compulsory inclusion of forage legumes in grass swards

Most policies aimed at promoting legumes focus on grain legumes, where either the seed is the principal product. A different form of utilising legumes in agriculture is to grow them on grassland, inter-sown with grass. Clover is a common type of legume used in this way. We have therefore supposed a policy which makes the inclusion of clover compulsory. The requirement under this policy would be that 25% of the total of grassland plus forage in any member state must consist of legumes.

The potential for modelling forage legumes in CAPRI is somewhat limited at present, and it has not been done before. CAPRI does not contain any forage crops other than silage maize, but it does have data on the percentage of clover in grassland. Hence it is this quantity which is manipulated here. As Map 1 shows, the percentage of clover varies strongly by country, from less than one percent in some countries to over 10% in others. The average for the EU as a whole is 5.2%. The variation is the result of farmers' considerations regarding the advantages and drawbacks of sowing clover in pasture areas. Generally, the production of grass-clover mixes in terms of dry matter by weight is lower than pure grass stands (Table 1).



Map 1. Clover as a percentage of grassland + pure clover, 2009[44]

The impact of clover on the energy and protein content of the grassland is less clear. For example, In the Netherlands the energy content decreases with the percentage of clover, while in the German state of Brandenburg it increases. In Sweden and Denmark the content is unchanged, while in Ireland the energy content is not measured or measured differently. The protein content of grass-clover mixes is higher than that of grass alone in Brandenburg and in Denmark, but (somewhat surprisingly) lower in the Netherlands and in Ireland.

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[44] Source: CAPRI database.

Table 1. Technical characteristics of grassland as affected by the technique (conventional or with clover) in five regions[45]

		Fertiliser input (kg N per ha)[46]	**Production (t dm/ha)[47]**	**Clover (%)**	**Net energy [48] (MJ NEL /kg dm)**	**Crude protein (gr/kg dm)**
Netherlands	Grass only	480	10	0	6.9	225
	With clover	130	9	46	6.6	223
Brandenburg	Grass only	197	8.2	0	5.0	130
	With clover	0	7.4	75	6.1	164
Sweden	Grass only	225	9	0	6.1	160
	With clover	110	9	30	6.2	160
Denmark	Grass only	350	9.7	0	6.6	170
	With small clover share	250	8.5	25	6.6	175
	With high clover share	65	8.1	60	6.6	190
Ireland	Grass only	504	12.5	6		219
	With clover	359	11.5	22		209

On the other hand, the need for nitrogen fertiliser is significantly lower in grass-clover mixtures: lower costs compensate for lower revenues. This may however be a disadvantage in countries with large surpluses of animal manure. That may be a reason for the low popularity of clover in Belgium and the Netherlands.

Although the acreage of grass-clover swards can be quite substantial, it is not modelled as a separate activity in CAPRI. However, the share of clover in total grassland is included in the calculation of the average percentage of biological fixation per ha grassland.[49] The nitrogen balance included in CAPRI is defined such that the managed nitrogen demand[50] can be supplied by nitrogen from mineral fertiliser, animal manure, crop residues and biological fixation. Within CAPRI it is assumed that biological fixation equals 5% of nitrogen retention, both on permanent and temporary grassland. This 5%

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[45] Source: expert information.

[46] Includes N from mineral fertiliser and animal manure, excluding biologically fixed N.

[47] DM=dry matter.

[48] MJ NEL=megajoule net energy lactation.

[49] In fact, the share of clover is included in biological fixation of temporary grassland in the standard baseline scenario. To simplify the programming we have changed this to total grassland. However, this also affects baseline results. Therefore, the baseline of the grassland clover scenario slightly differs from other scenarios presented in this deliverable.

[50] Managed nitrogen demand equals nitrogen retention plus a certain amount of overfertilisation. The latter is derived from information about observed purchases of nitrogen from mineral fertiliser, available nitrogen in animal manure and crop residues, engineering information and applying statistical techniques.

is used in all regions.[51] For clover, biological fixation is assumed equal to 75% of the nitrogen retention (export of N with crop harvest). Thus, if the acreage of clover is 10% of the acreage of clover plus grassland (temporary and permanent), N fixation is equal to 90*5%+10*75% = 12%.

3.7 Carbon tax

In this scenario we analyse the impact of a CO_2 emission tax on agricultural production and emissions in the EU-27. Taxing CO_2 emissions is an alternative to the present emissions trading system practised in the EU.[52] In order not to lay an additional tax on the agricultural sector as a whole, but only to encourage climate-mitigation measures by farmers, we assume that the proceeds of the tax are returned to farmers in the form of subsidies for environmentally sustainable agriculture. Part of this is a subsidy for carbon storage in the soil, equivalent to the climate-mitigation effect.

3.7.1 Current GHG emissions from agriculture

The main sources of greenhouse gases from the agricultural sector are methane (CH_4, a by-product of the digestive system of animals), carbon dioxide (CO_2, emitted during the manufacturing of nitrogen fertiliser), and nitrous oxide (N_2O, emitted from fields where nitrogen fertiliser is applied but also emitted from animal manure and from fertiliser during manufacturing). Table 2 shows the average methane emission per head in the EU-27, current and predicted. Differences between member states and regions can be quite large: in dairy cows, for example, it ranges from 50-65 kg per head in parts of France and Greece to 137 kg per head in Denmark (under low-yield conditions).

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[51] The Irish data show that biologically fixed N was 12 kg/ha for conventional grassland and 112 kg/ha for the grass/clover mix (James Humphreys, personal communication).

[52] Goulder, L.H., Schein, A.R., 2013. Carbon Taxes vs. Cap and Trade: A Critical Review. Stanford University.

Table 2: Average methane (CH_4) emission calculated with IPCC Tier 2 in the EU-27 in 2007/2009 and in 2020 under the reference scenario (kg per head)

	2007/2009		***2020***	
	Enteric fermentation	manure management	Enteric fermentation	manure management
Dairy cow (low yield)	108.3	13.6	115.8	16.5
Dairy cow (high yield)	135.6	16.6	145.3	19.7
Male adult fattening low final weight	34.4	2.2	35.9	2.4
Male adult fattening high final weight	77.2	4.6	82.1	5.2
Heifers fattening low final weight	28.9	1.8	32.2	2.0
Heifers fattening high final weight	71.0	4.4	78.2	4.8
Suckler cows	64.1	3.7	64.5	3.6
Heifers raising	76.1	5.6	76.0	5.9
Calves male fattening	14.6	0.9	15.2	1.0
Calves female fattening	14.3	0.8	15.1	0.9
Calves male raising	30.0	2.0	30.5	2.1
Calves female raising	29.1	2.0	29.7	2.2
Pig fattening	0.5	2.1	0.5	2.1
Sows	1.5	8.8	1.5	9.0
Sheep and goats for milk production	8.0	0.2	8.0	0.2
Sheep and goats for fattening	2.8	0.1	2.8	0.1
Laying hens		26.1		13.4
Poultry fattening		2.8		1.6

Source: CAPRI database

The emissions from the manufacturing of mineral fertiliser depend on its composition. CO_2 and N_2O emissions per component are given in Table 3. As can be seen, CO_2 emissions occur primarily in N fertiliser, mostly in the maufacturing of ureum, one type of fertiliser. The share of ureum in N fertiliser can be quite different per member state (Table 4). Given a GHG emission tax, the tax on mineral fertiliser can be calculated.

Table 3: Greenhouse gas emissions per tonne of nutrient in mineral fertilisers produced (kg)

		CO_2	N_2O
Nitrogen	Ureum	4018.9	0.0
	Other	2438.4	9.0
Phosphate		972.7	4.3
Potassium		140.0	0.6

Source: Wood and Cowie, 2004[53]

Table 4: Share of ureum and other components in N fertiliser (fraction)

	Ureum	Other
Belgium & Luxembourg	0.012	0.988
Denmark	0.006	0.994
Germany	0.158	0.842
Greece	0.021	0.979
Spain	0.258	0.742
France	0.086	0.914
Ireland	0.144	0.856
Italy	0.478	0.522
Netherlands	0.003	0.997
Austria	0.014	0.986
Portugal	0.115	0.885
Sweden	0.001	0.999
Finland	0.009	0.991
UK	0.086	0.914
Czech Republic	0.016	0.984
Hungary	0.126	0.874
Poland	0.345	0.655
Slovenia	0.149	0.851
Slovakia	0.104	0.896
Estonia	0.017	0.983
Lithuania		1
Latvia	0.322	0.678
Cyprus	0.077	0.923
Malta		1
Bulgaria	0.05	0.95
Romania	0.05	0.95

Source: CAPRI database

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[53] Wood, S., Cowie, A., 2004. A Review of Greenhouse Gas Emission Factors for Fertiliser Production. West Pennant Hills (Aus.), State Forests of New South Wales.

Table 5 shows the average N_2O emission per crop per ha. During simulation it is assumed that the emission of the extensive technology is 20% below the average emission per crop per ha, while the emission of the intensive technology is 20% above the average. Again, differences between member states and regions can be large. N_2O emissions from soft wheat range from less than 0.6 $kg.ha^{-1}$ in regions in Italy, Greece, Spain and Portugal to more than 6 $kg.ha^{-1}$ in regions in Belgium and the Netherlands.

Table 5. Average N_2O emissions in 2007/2009 and in 2020 in the reference scenario (selected activities, kg per head or ha)

	2007/2009	**2020**
Soft wheat	2.9	3.2
Rye	1.6	1.7
Barley	2.1	2.3
Oats	2	2.1
Grain maize	3.1	3.9
Other cereals	2.3	2.7
Rape seed	3	3.3
Sunflower seed	1.3	1.6
Soyabeans[1]	1.9	1.8
Fodder maize	1.8	2.2
Other feed on arable land (e.g. temporary grassland)	3.7	4.3
Grassland extensive	1.4	1.6
Grassland intensive	2.8	3.2
Pulses[1]	0.8	0.7
Potatoes	3	3.4
Sugar beets	6.2	6.2
Dairy cow low yield	3.1	3.5
Dairy cow high yield	4	4.3
Male adult fattening low final weight	1.1	1.1
Male adult fattening high final weight	1.9	2
Heifers fattening low final weight	1	1.1
Heifers fattening high final weight	2	2.1
Suckler cows	2.7	2.8
Heifers raising	3.1	3.2
Laying hens	19.1	21.2
Poultry fattening	3.2	3.6

Note: N_2O emission from biological nitrogen fixation has been put equal to zero.
Source: CAPRI database

Table 6 gives the average application of mineral fertiliser by nutrients and the average mineral fertiliser costs as a percentage of output value in the EU-27 in the 2007/2009 period. Mineral fertiliser cost shares ranges from about 10-12% in Romania and

Bulgaria to about 45% in Finland. The larger the cost share, the larger will be the impact of the CO_2 emission tax on agricultural production

Table 6: Average Nitrogen, Phosphor and Potassium from mineral fertiliser in EU-27 in period 2007/2009 (selected activities, kg per ha) and cost share (%)

Crop	Nitrogen	Phosphorus	Potassium	Cost share in total output per ha
Soft wheat	124	26	29	22
Rye	56	18	17	17
Barley	80	21	25	20
Oats	59	23	24	24
Grain maize	95	39	23	17
Other cereals	97	24	23	23
Rape seed	98	24	10	14
Sunflower seed	38	13	10	13
Soyabeans	27	44	40	18
Fodder maize	42	8	9	6
Other feed on arable land (e.g. temporary grassland)	21	2	4	5
Grassland extensive	20	1	2	14
Grassland intensive	48	3	4	15
Pulses	10	17	19	10
Potatoes	107	36	126	5
Sugar beet	159	84	160	18

Legumes, in CAPRI represented by pulses and soybean, are presumed to lead to 1.83 $tonnes.ha^{-1}$ of additional carbon storage compared to non-legumes is assumed to be.

3.7.2. Scenarios

Four scenarios are included (see Table 7). The carbon tax equals either 18 € or 72 € per tonne of CO_2 equivalent. Besides the tax there is also a CO_2 storage premium included for pulses and soybeans. The premium is calculated as CO_2 storage ($tonnes.ha^{-1}$) times the price of CO_2 (€ per tonne). CO_2 storage per ha is assumed equal to $1.83*44/12\ t.ha^{-1}$ for soybeans and pulses and equal for all regions.

The reimbursement to labour is calculated such that the revenues from the carbon tax on agricultural activities and on the production of mineral fertiliser, minus the CO_2 storage premium on pulses and soya is exhausted per member state. In doing so, the total available budget per member state is divided by the total number of labour hours spent on agricultural activities. This gives the subsidy or premium per hour. To calculate the subsidy per activity, the number of hours per activity is multiplied with the subsidy per hour per member state. Data on labour hours per agricultural activity per member state is taken from the CAPRI database.[54]

Table 7: Scenario variants

	CarbonA1	CarbonA2	CarbonB1	CarbonB2
CO2 price (€/ton)	18	18	72	72
CO2 storage premium on pulses and soya	Yes, 18 €/ton CO_2	Yes, 18 €/ton CO_2	Yes, 72 €/ton CO_2	Yes, 72 €/ton CO_2
Reimbursement to labour (€/hour)	yes	no	yes	no

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[54] Britz, W., Witzke, P., 2012. CAPRI model documentation 2012. http://www.capri-model.org/docs/capri_documentation.pdf

4. THE CAPRI MODEL[55]

CAPRI stands for Common Agricultural Policy Regional Impact. It is a global partial equilibrium model for the agriculture sector with a focus on the EU-27, plus Norway and the Western Balkans. It calculates the effects of EU agricultural and trade policy on production, income, markets, trade and the environment from a global to a regional scale (NUTS2). CAPRI was developed initially at the University of Bonn in Germany (http://www.capri-model.org), but it is now supported by a pan-European network of researchers of which LEI is a member. The CAPRI modelling system consists of a methodology, databases, software implementation and, of course, researchers.

4.1 Components of the model

The CAPRI model contains two interlinked components: a supply module and a trade or market module.

The supply module consists of 1,888 non-linear programming models representing up to 10 farm types in each NUTS2 region. The data are based on the Economic Accounts for Agriculture (EAA). The farm models have fixed input-output coefficients for each production activity with respect to land and intermediate inputs. Normally a low and high yield variant for the different production activities are modelled. Requirements regarding NPK balances and feeding requirements of animals are taken into account. A land supply module allows for land leaving and entering the agricultural sector and transformation between arable and grass land in response to relative price changes.[56] These models cover around 50 crop and animal activities for each of the farm types and include around 50 different inputs and outputs.[57]

The trade module is a comparative static spatial global multi-commodity model. It covers 47 primary and secondary agricultural products and models bi-lateral trade between 60 countries grouped in 28 trade blocks. The CAPRI market model is iteratively linked in a transparent and consistent way to the layer of non-linear regional mathematical programming models. Apart from marketable agricultural outputs, it contains a specific sub-component that models the feed market. Bi-lateral trade flows

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[55] The description in this chapter is adapted from Woltjer, G., Bezlepkina, I., Leeuwen, M. van, Helming, J., Bunte, F., Buisman, E., Luesink, H., Kruseman, G., Polman, N., Veen H. van der, Verwaart, T., 2011. The agricultural world in equations: An overview of the main models used at LEI. Memorandum 11-151, LEI, The Hague.

[56] Jansson, T., Kuiper, M., Adenäuer, M., 2009. Linking CAPRI and GTAP. SEAMLESS Report no. 39, SEAMLESS integrated project, EU 6th Framework Programme, contract no. 010036-2. www.seamless-ip.org/Reports/Report_39_D3.8.3.pdf.

[57] Gocht, A., Britz, W., Adenäuer, M., 2011. Farm level policy scenario analysis. IPTS, Seville.

are modelled using the Armington assumptions.[58] The behavioural equations for supply, feed, processing and human consumption have flexible functional forms. Calibration algorithms make the coefficients in these functions consistent with micro-economic theory.

Labour and capital costs are captured by a non-linear cost function (the so-called Positive Mathematical Programming methodology). These non-linear cost functions are calibrated in such a way that they mimic the base data and capture information about supply elasticities. The models allow for a lot of detail in CAP subsidies. A special component captures the complex sugar quota regime. This component maximizes expected utility from stochastic revenues. Prices are exogenous in the supply module and provided by the market module. Grass, silage and manure are non-tradable and receive accounting prices based on opportunity costs.

Policy instruments in the market module cover Product Support Equivalents and Consumer Support Equivalents (PSE/CSE) from the OECD, (bi-lateral) tariffs, the Tariff Rate Quota (TRQ) mechanism and, for the EU, intervention stocks and subsidized exports. This sub-module delivers prices used in the supply module and allows for market analysis at global, EU and national scale, including a welfare analysis.

As the supply models are solved independently at fixed prices, the link between the supply and market modules is based on an iterative procedure. After each iteration, during which the supply module works with fixed prices, the constant terms of the behavioural functions for supply and feed demand are calibrated to the results of the regional aggregate programming models aggregated to a country level. Solving the market modules then delivers new prices. A weighted average of the prices from past iterations defines the prices used in the next iteration of the supply module. Equally, in between iterations, CAP premiums are re-calculated to ensure compliance with national ceilings.

CAPRI uses templates that are filled with different parameter sets for different regions and products. This reduces maintenance cost and makes results comparable across products, activities and regions. The modular setup allows to use the different components also independently.

The model has a lot of flexibility because of its modular approach (see also Figure 2). Regional supply models may be used without the market model, while the market model works also without the explicit farm models. The model can be used both in a comparative dynamic and in a static way.

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[58] Armington, P.S., 1969. A Theory of Demand for Products Distinguished by Place of Production. IMF Staff Papers 16, 159-78.

An extensive post-model analysis is provided. Income indicators are calculated consistent with the EAA methodology. A welfare analysis is possible. A detailed account of the First-Pillar CAP outlays is available. NPK balances are calculated, while climate-relevant gases are computed consistent with the guidelines of the Intergovernmental Panel on Climate Change (IPCC). Model results are presented as interactive maps and as thematic interactive drill-down tables.

The maintenance of CAPRI is based on the open-source network concept. Databases and model code, including the GUI, are hosted on the software versioning and repository system (SVN) server, from which they can be downloaded and incrementally updated. Selected developers may also commit changes to the server. “The CAPRI modelling system may be defined as a ‘club good’: there are no fees attached to its use but the entry in the network is controlled by the current club members. The members contribute by acquiring new projects, by quality control of data, new methodological approaches, model results and technical solutions, and by organizing events such as project meetings or training sessions. So far, the network approach worked quite successfully but it might need revision if the club exceeds a certain size.”[59]

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[59] Britz, W. and Witzke, P., 2008. CAPRI model documentation 2008, Version 2, University of Bonn. (www.caprimodel.org/).

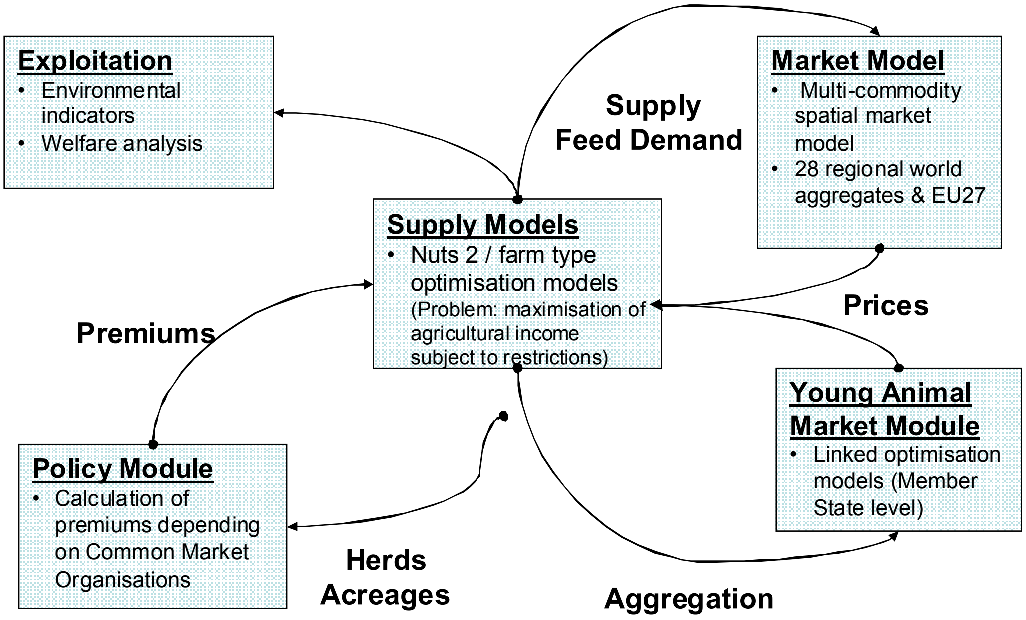

Figure 2. The Capri model chain[60]

4.2 Required input

The data bases exploit wherever possible well-documented, official and harmonized data sources, especially data from EUROSTAT, FAOSTAT, OECD and extractions from the Farm Accounting Data Network (FADN). Specific modules ensure that the data used in CAPRI are mutually compatible and complete in time and space. They cover about 50 agricultural primary and processed products for the EU, from farm type to global scale including input and output coefficients.

4.2.1 Base Period Variables

The database of CAPRI is created in three steps:

1. CoCo — Completeness and consistency. This module creates a complete (no gaps) and consistent (satisfying the CAPRI physical and economic equations) database at member state level from about 20 years back to the most current date. Key sources are EUROSTAT for agricultural production and yields as well as the Economic Accounts for Agriculture (EAA).

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[60] Source: Britz, W., Heckelei, T., Kempen, M. (eds.), 2007. Description of the CAPRI modelling system. Final report of the CAPRI-Dynaspat project. Institute for Food and Resource Economics, University of Bonn, 2007.

2. CAPREG — Regionalization of the CoCo database. Based on the REGIO database on production and yields at a NUTS2 level, the CoCo database is broken down into regions. CAPREG also uses engineering information to estimate fertilization and animal feeding per production activity and region, and manually collected information from EC regulations on direct payments and quotas to calculate gross value added and income. CAPREG uses a three-year average around the base year to prevent excessive influence of ephemeral fluctuations. The supply models are calibrated at that point.

3. GLOBAL — Creation of a harmonized global database on bilateral trade flows and trade instruments. GLOBAL processes data from FAOSTAT.

4.2.2 Parameters

CAPRI contains a large number of parameters, especially concerning the biophysical processes involved in animal feeding and fertilization. The core parameters in the simulations are the behavioural parameters for supply and demand:

1. Supply elasticities. The behaviour of producers is governed by a quadratic cost function. The parameters are based on regionalized time series produced by CAPREG using a Highest Posterior Density (HPD) estimator that includes the first-order conditions of the supply model and weak priors for own-price elasticities.

2. Demand elasticities. The parameters of the Generalised Leontief expenditure system are obtained by an HPD using synthetic elasticities as priors and the demand system equations and economic theory (curvature etc) as estimating equations.

3. Armington substitution elasticities for imports versus domestic products are set manually to synthetic values or to values prescribed by the scenario definition.

4.2.3 Scenario projection variables

For the baseline (reference) scenario, the model is recalibrated to a projection that is generated by a combination of the module CAPTRD (for the supply model) and CAPMOD (for the market model).

1. CAPTRD makes a projection of the CAPREG database to a selected future year. The projection is based on, in order of significance, (a) the Agricultural Outlook of the European Commission; (b) exponential trends fitted to the CAPREG data (for a regional breakdown); (c) a simulation of the baseline policy in the base year; and (d) expert information, especially where (a) is not present and (b) and (c) fail.

2. CAPMOD contains procedures for projecting the market model base data of GLOBAL to a future year. It is based on (a) supply utilization accounts from FAO; (b) projection from FAO's AT2030; (c) trade flows from FAO; (d) COCO/CAPREG data for the market model; (e) population data; (f) growth rates from CAPRI, plus the requirement that the model calibrates in the future point (model equations).

3. Agricultural policies, essentially (a) payment ceilings in physical or economic terms; (b) payment amounts; (c) eligible activities; (d) set-aside rates; (e) quotas for milk and sugar; (f) intervention prices; (g) WTO limits on intervention and export subsidies; (h) ad-valorem and specific tariffs; (i) trigger prices; (j) minimum border prices; (k) global and bilateral tariff rate quotas with associated volumes and tariff rates.

4.3 Output of the model

The supply module generates information about activity levels (hectares, animals), feeding, fertilizer use, and sales. The market model generates trade flows, production, use of agricultural products by the processing industry, animals and humans, bioenergy use, market, producer and consumer prices, profit margins, prices of milk fat and protein, export subsidies, tariffs, and intervention purchases and stocks.

Many additional indicators are computed, including agricultural income, consumer welfare, CAP budget effects (disaggregated into individual payments, intervention and export subsidies), processor profits, nutrient balances at soil level, greenhouse gas inventories, self-sufficiency in agricultural products, labour and energy indicators

4.4 Strengths and weaknesses

CAPRI has a lot of sectoral and regional detail in the agricultural sector, enabling simulation of agricultural policies in a unified manner for NUTS2 regions in the EU. It is the only model that can do this. The good regional detail is matched by endogenous world trade and prices with a theory-consistent demand system.

The modular setup makes it very suitable for extension, but the way a lot of modules are programmed makes the model not easy to handle and interpret; it requires a lot of expertise to do this.

The model includes very explicit technological assumptions, facilitating implementation of technical constraints on fertilization, feeding or land use. Nevertheless, the model only contains variable costs explicitly, whereas fixed costs are subsumed by a quadratic cost function. The quadratic function is estimated based on time series,[61] and ensures perfect calibration on the base year as well as realistic supply responses in the medium term. The quadratic function may also be calibrated on elasticities derived from other models or mechanisms, and thus be used in linking.

The model is in fact a combination of supply models and a market model. This means that the model itself provides an advanced way to link models that may be an example for linkage between other models.

The advantage of the CAPRI database is its consistency and completeness. However, in order to achieve this consistency many heroic assumptions have to be made.

CAPRI is a club good for technical reasons, i.e. its use is restricted to members. A tremendous investment in human capital is required in order to join the club. The club good character makes it difficult to attract new researchers, but also works as a quality control for studies with CAPRI.

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[61] Jansson, T., Heckelei, T., 2009. A new estimator for trade costs and its small sample properties. Economic Modelling 26:2, 489-498.

5. RESULTS

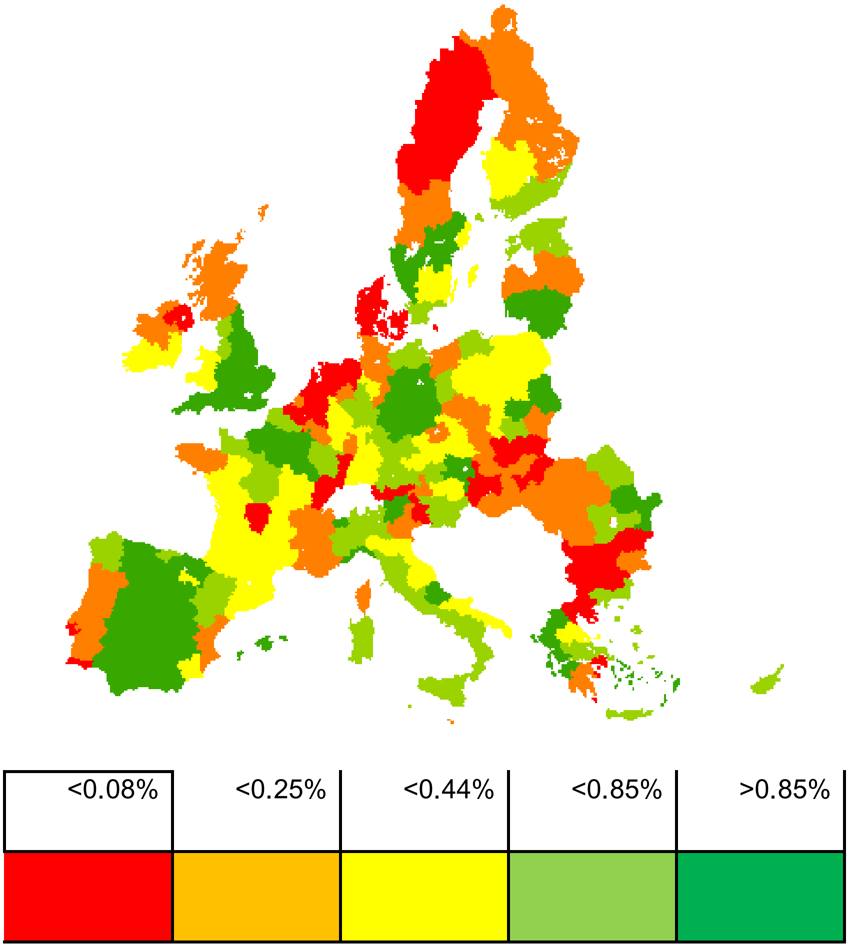
5.1 Reference scenario

In the reference scenario, i.e. with a continuation of current trends, there will be a further decline in the cultivation of legumes. The area under pulses will decrease by 327,000 hectares or 24% over the period 2009-2020. Cultivation of soybean will increase, by 213,000 hectares or 70%, meaning an overall net loss of 114,000 hectares for grain legumes, or 7% of the grain legume area in 2009. Figures per country are shown in Table 8. Strong increases are due to an expansion of soybean cultivation in countries where the climate is suitable and where soybean is presently grown only on a small scale.

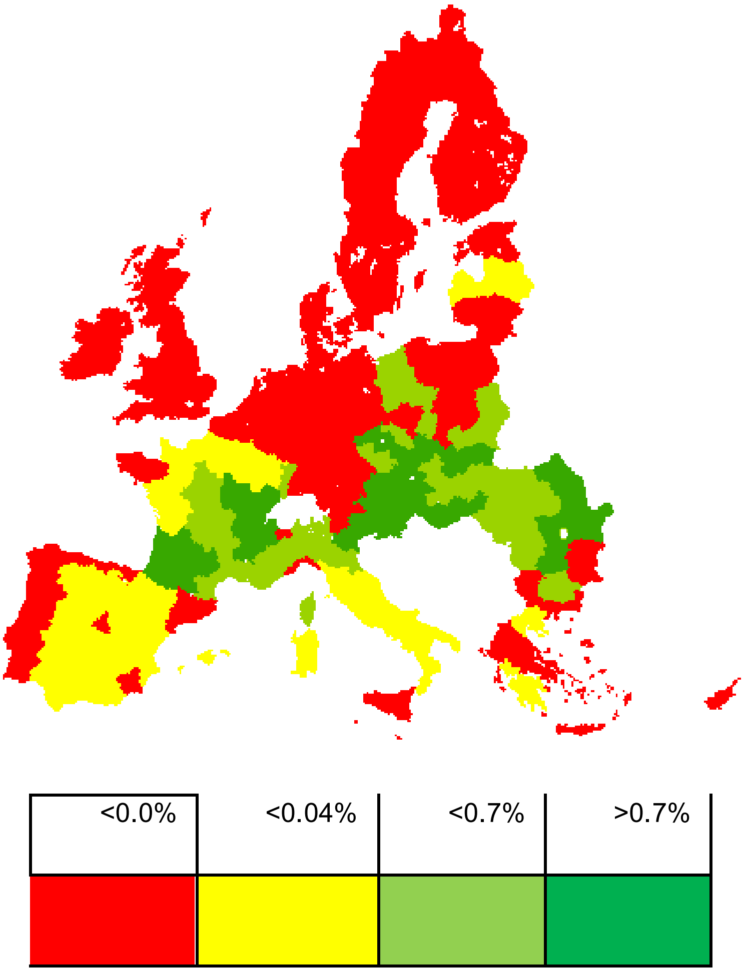
Table 8. Area under grain legumes, 2009-2020

	2009		***2020 (reference scenario)***		***% change***
	'000 hectares	*as % of arable*	*'000 hectares*	*as % of arable*	*in area*
Belgium	2	0.2%	1	0.1%	-68%
Denmark	7	0.3%	2	0.1%	-75%
Germany	83	0.7%	81	0.6%	-2%
Austria	47	3.3%	84	5.5%	80%
Netherlands	3	0.3%	0	0.0%	-84%
France	263	1.3%	221	1.1%	-16%
Portugal	15	0.7%	4	0.2%	-74%
Spain	315	1.8%	309	1.8%	-2%
Greece	21	0.6%	19	0.6%	-8%
Italy	210	2.1%	92	0.9%	-56%
Ireland	4	0.4%	3	0.3%	-11%
Finland	7	0.3%	7	0.3%	3%
Sweden	26	1.0%	15	0.6%	-41%
United Kingdom	242	4.0%	191	3.1%	-21%
Czech Republic	36	0.7%	69	2.3%	92%
Estonia	5	0.2%	5	0.8%	-7%
Hungary	52	4.3%	87	1.8%	68%
Lithuania	47	0.3%	43	2.1%	-10%
Latvia	3	1.6%	2	0.2%	-39%
Poland	129	8.8%	79	0.6%	-39%
Slovenia	1	0.6%	6	2.7%	582%
Slovakia	20	205.2%	24	1.6%	18%
Cyprus	2	0.0%	1	0.8%	-19%
Malta	0	0.0%	0	0.2%	-33%
Bulgaria	8	0.8%	45	1.3%	474%
Romania	104	14.2%	148	1.5%	43%
EU-27	**1,652**	**1.3%**	**1,538**	**1.2%**	**-7%**

Map 2 and Map 3 below show the shares of pulses and soybeans in the total Utilised Agricultural Area per region (UAAR) in 2020 in the reference scenario. It appears that regions with a relatively high share of pulses in several regions of Europe: Lithuania, England, Spain, southern Sweden, eastern Germany, northern France, eastern Romania and parts of Greece. Soybeans are grown much less than pulses (compare Map 2 with Map 3). Relatively high shares can be found in southern and central France, several Central European countries and Romania.



Map 2. Share of pulses in total UAAR per NUTS2 region in 2020 (reference scenario)



Map 3. Share of soybeans in total UAAR per NUTS2 region in 2020 (reference scenario)

Table 9 shows the average fertilisation balance for some selected crops in the EU-27, as given by CAPRI. Pulses and soybeans clearly make a positive contribution in that they require much less N fertiliser. Moreover, if harvested they can serve to remove excess nitrogen from the soil.

Table 9. EU-27 average fertilisation balance per crop in 2020 in the reference scenario

	Mineral nitrogen	**Manure nitrogen**	**Other nitrogen**	**Nitrogen removed**	**Nitrogen surplus**
	kg N per hectare				
Soft wheat	123	20	52	-149	46
Durum wheat	79	15	25	-89	31
Rye and Maslin	54	17	36	-80	27
Barley	80	20	36	-100	36
Oats	61	17	36	-80	33
Grain Maize	113	52	120	-214	71
Other cereals	104	29	61	-143	51
Paddy rice	158	38	92	-221	67
Rape	161	6	71	-182	56
Sunflower	69	4	49	-91	31
Soya	37	12	32	-227	-146
Other oilseeds	71	2	39	-83	29
Pulses	12	4	37	-128	-75
Potatoes	119	22	71	-160	52
Sugar Beet	174	27	209	304	105
Fodder maize	60	189	23	180	92
Fodder root crops	80	30	61	123	48
Fodder other on arable land	29	96	45	157	14
Extensive pasture	20	24	30	52	21
Intensive pasture	45	56	70	122	49

5.2 Increasing worldwide use of GM soya

This section is based on an earlier study by Nowicki et al.[62] Here we only present the main findings of that study as relevant to the prospects for legume cultivation in Europe. Environmental impacts were not calculated in this study, but we discuss these in general terms in subsection 5.2.5.

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[62] 2010, op. cit. (see note 42)

5.2.1 Disruption of soy imports

Profit margins in the soy trade are low. With increasing worldwide use of GM soy varieties, the risk for traders of having their shipments condemned increases considerably, and this may lead to short- or long-term disruption of the trade. Nowicki et al. modelled two scenarios for short-term disruption and two for long-term disruption (with 2020 as the horizon). The former will have significant consequences for livestock production, but because of their short-term nature are unlikely to act as a major stimulus for legume production in Europe. For the long term there is a moderate scenario, called blue, in which there are on average once-yearly incidents with low-level presence of unapproved varieties, and the USA is lost as a supplier. Under the more serious scenario, called red, many new GMO varieties are introduced in all major soy-exporting countries which have not (yet) been approved in the EU. Because segregation is not economically feasible, importation of soy would grind to a halt. Only Canada, where GM soy varieties are segregated from non-GM crops, could still supply soy to Europe. This scenario is characterised as highly probable.[63]

It would lead to multiple results through complex mechanisms. The European livestock sector would generally become less competitive compared to other parts of the world. This in turn could lead to a decrease of livestock production in Europe – at least in comparison to the reference scenario. Livestock products would become more expensive, and consumption of livestock products might decrease. The soy-crushing industry would suffer too. On the other hand, production of protein crops (i.e. legumes) in the EU would increase, as the demand for both soy and its potential substitutes rises.

5.2.2 Land use effects

In figures: the most direct result of the red scenario would be a shortage of 45 million tonnes of soy and in the medium term (2020) a structural price increase of 138% for soybeans and 107% for soymeal.[64] By then, some new exporters would emerge to benefit from the opportunities of supplying soy to the EU at a high price. In Europe itself, the area under soybean would increase from 500,000 ha under the reference scenario to 1.2 million hectares (an increase of 130%). Map 4 indicates where this increase in cultivation is likely to take place. The increase in production would be even larger (155%), because the higher price is also an incentive to increase yields.

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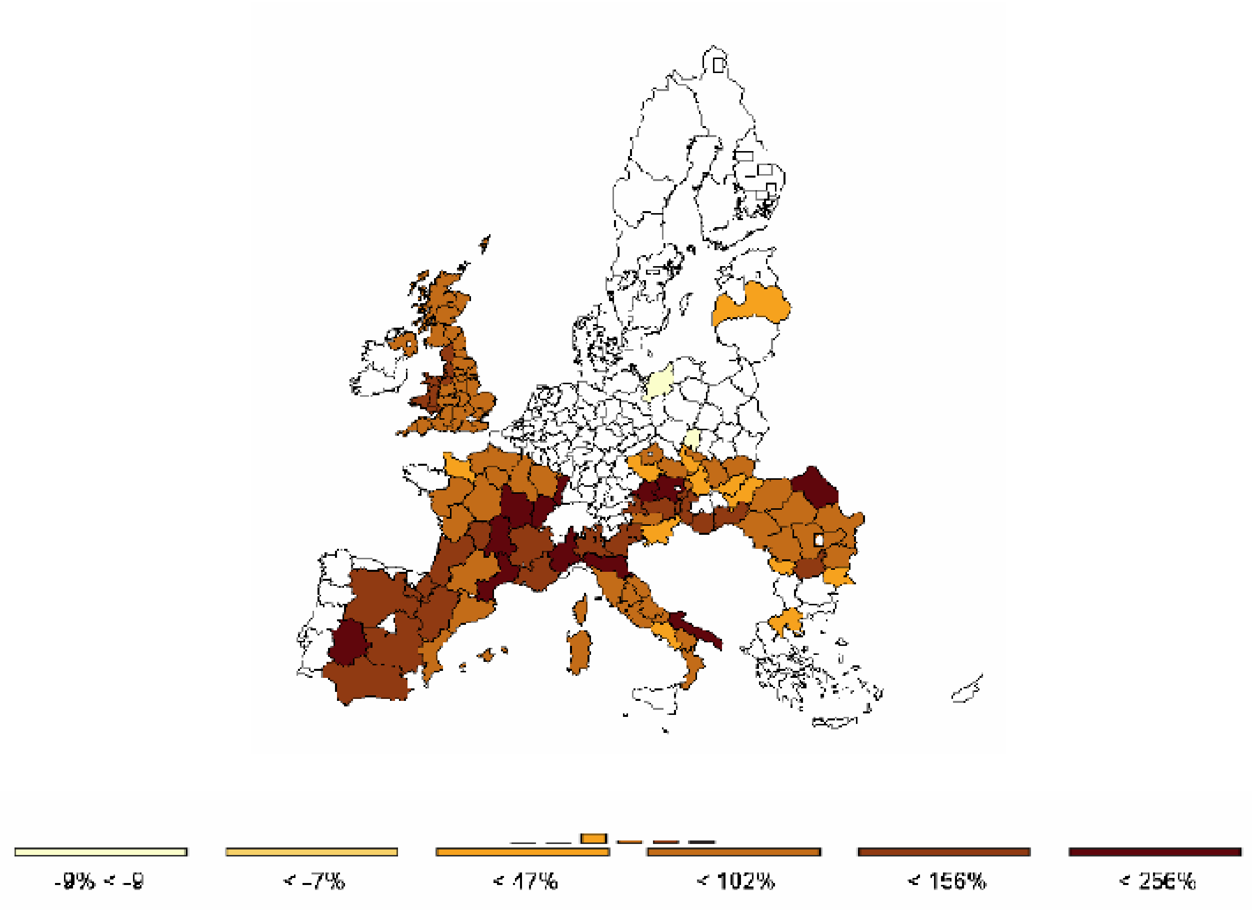
[63] Nowicki op. cit., p. 83.

[64] Nowicki op. cit., p. 100. The short-term price rise would be much higher



Map 4. Increased cultivation of soybean under GMO-red scenario[65]

The main substitute for soy which is modelled in CAPRI is peas, faba beans and other pulses, and their cultivation would increase by some 500,000 ha, an increase of 37% compared to the reference scenario. Peas, beans and other pulses are grown far more widely than soybean, so the effect on land use would be felt throughout the EU (Map 5). Production of these crops increases by 1.3 million tonnes, or 49% higher than the reference. This expansion of legume cultivation comes at the expense of other land uses, including land which is fallow or under extensive management to the extent of 0.8 million hectares (5% decrease in this type of land management. On the other hand, since soy is also a source of edible oil and we assume these oil imports are also affected, the production of other oilseeds (sunflower, rapeseed) would need to increase (next to the importation of palm oil); and, since the GMO problem also affects the import of maize, the area under fodder crops would increase as well. Hence, the area under other arable crops (e.g. wheat, sugar-beet, potato) would decrease, by almost a million

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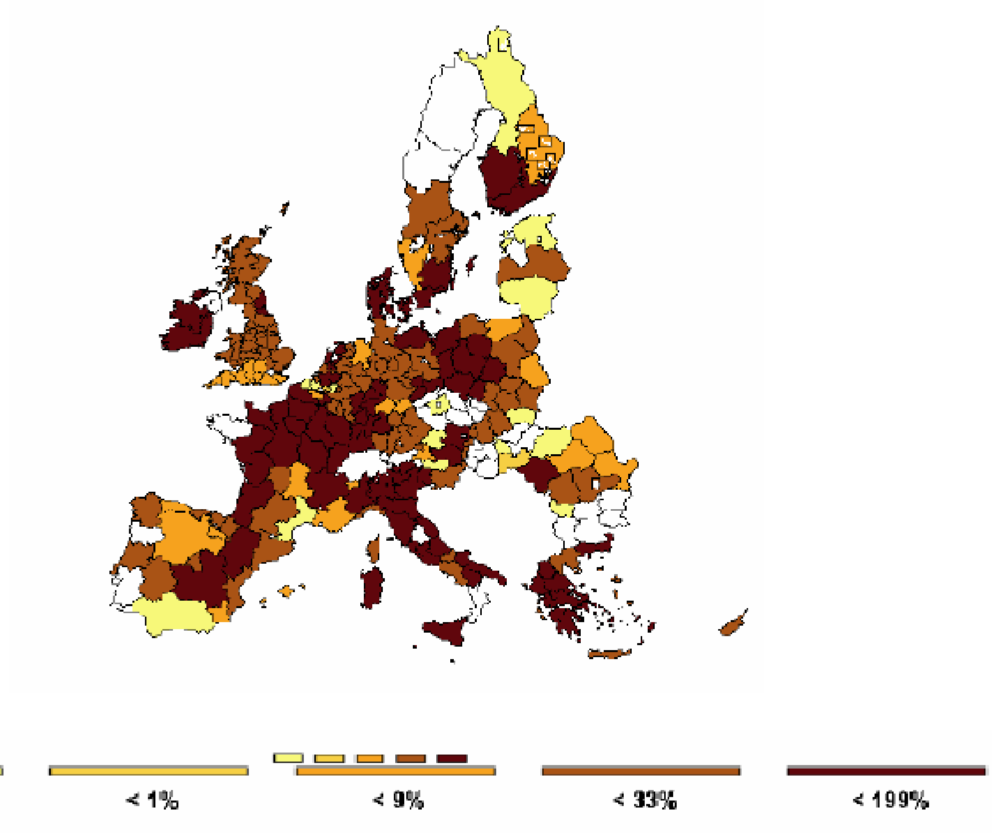
[65] Source: Nowicki op. cit., p. 118. It must be noted that CAPRI can only model increases in regions where the crop in question is already grown.

hectares. Another 100,000 hectares under vegetables and permanent crops would also be converted to the production of legumes, oilseeds or maize.



Map 5. Increased cultivation of pulses in GMO-red scenario[66]

5.2.3 Economic impact

Nowicki et al.[67] conclude that the overall negative economic effect of the GMO-red scenario is mostly on the consumer: the higher prices of animal products cost them about € 10,500 million per year. The farming sector as a whole does not really lose, as losses in the livestock sector are counterbalanced by gains in arable farming; it does, however, entail redistribution between farmers.

5.2.4 Conclusions

Clearly, this scenario, if it materialized, will have a very large positive impact on the cultivation of legumes. It would reverse the trend of declining production and therewith redress, to a significant extent, the lost balance between legumes and cereals. As a result, European soils would be managed more sustainably and greenhouse-gas emissions from agriculture would be reduced. On the other hand, consumers would pay

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[66] Source: Nowicki, op. cit., p. 119.

[67] Op. cit., pp. 138-9.

a price – which some would regard as a good thing as meat consumption may be reduced. Livestock farmers, too, would suffer, but crop producers would benefit.

There will also be environmental effects outside Europe, as the negative impact of soy cultivation in exporting countries (alluded to in section 2.1) would be mitigated.

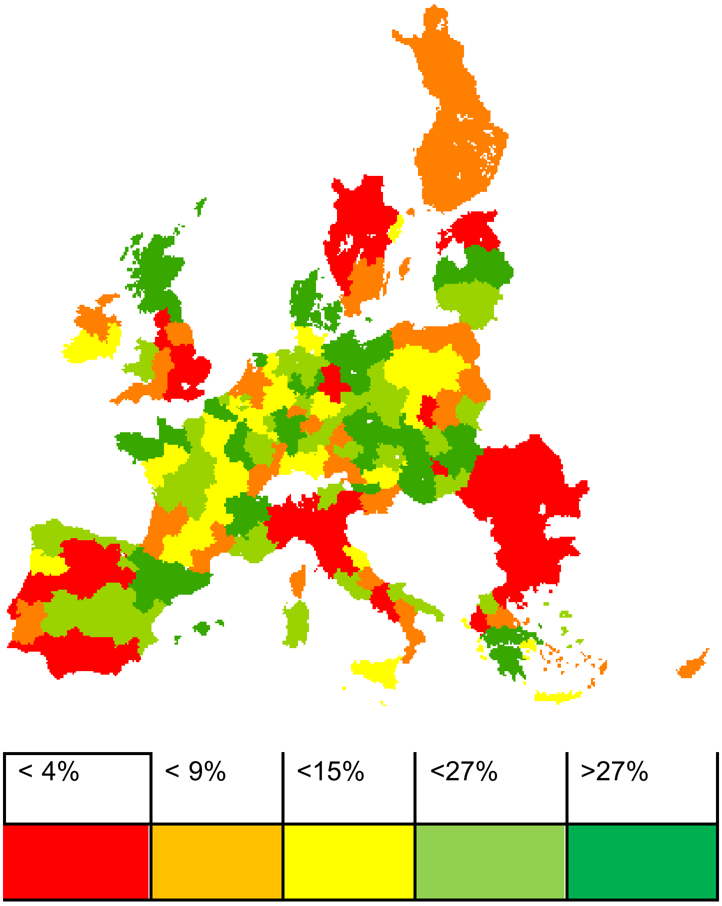
But how realistic is this scenario? It is quite plausible under current policies, but more than anything else this may indicate how unrealistic those policies are. Rather than sustain a major blow to livestock producers and consumers demanding cheap meat, the threat of disruption in the soy trade may focus policy-makers' minds and introduce thresholds for the presence of non-approved soy varieties. It is even conceivable that the ever-increasing use of GMO in other parts of the world will eventually convince Europeans of the futility of their attempts to keep GMO crops outside.

5.3 Premium per hectare for grain legumes

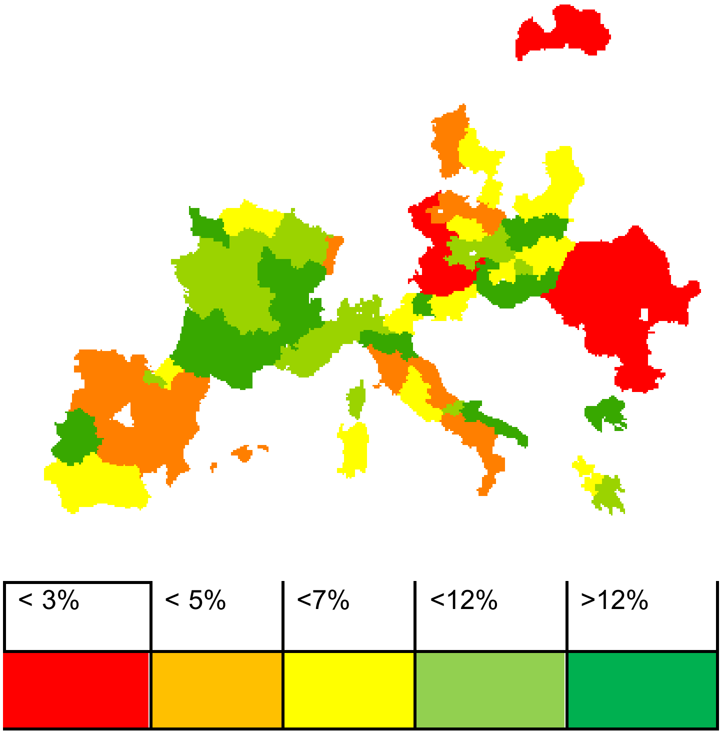
5.3.1 Land-use effects

An important question is to what extent these payments lead to more land cultivated with legumes. The area under pulses (peas and faba beans) increases by 13% compared to the reference scenario, and the area under soybean by 11%, for the EU-27 as a whole. This is modest compared to the steep decline that legume cultivation has undergone in recent years.

However, the effect by region is quite variable, as can be expected from the differential payments and the differences in production possibilities. The regional impact on acreage of pulses and soybeans is shown in Maps 6 and 7 respectively. Regions with relatively low increase in the area under pulses can be found in England, Spain, northern Italy and in Romania and Bulgaria. It should be noted that in general these regions already have a relatively high share of pulses in their regional cropping plan. As for soybean, the largest increases are found in France.



Map 6. Change in hectares of pulses per NUTS2 region (percentages)



Map 7. Change in hectares of soybeans per NUTS2 region (percentages)

However, these legume premiums also have an impact on the total agricultural area. The total UAA in the EU-27 decreases by 0.015%, or about 27,000 hectares. This is because direct farm payments decrease in regions with very little cultivation of legumes. The largest decrease, in the range of 0.1-0.2%, occurs in Scotland and in parts of northern of Spain (Asturias, Cantabria, the Basque Country and Galicia). Apart from the decrease of direct farm payments, this process is also influenced by high land supply elasticities: a limited shift in the profitability of agricultural production causes a relatively large shift in the supply of land for agriculture – in this case, farming becomes less profitable (because of the decrease of the direct regional farm payment, which is not offset by the increased regional payment for grain legumes) and hence land is taken out of agriculture – abandoned, as the case may be.

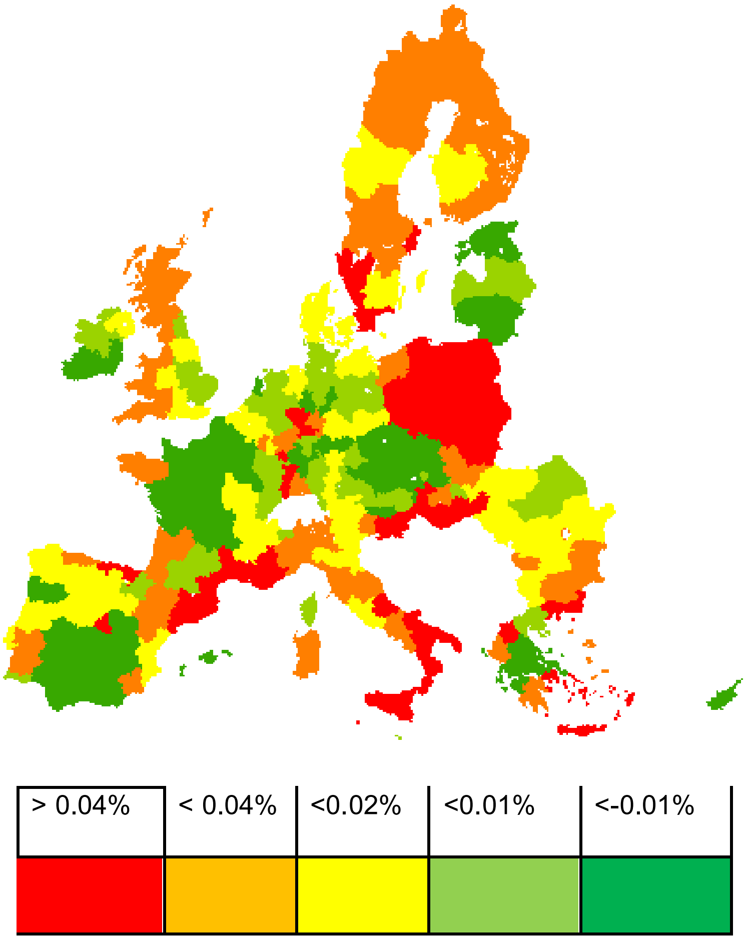
5.3.2 Environmental impact

Table 4 shows the impact on some selected environmental indicators in the EU-27 as a whole. Total global warming potential (GWPT), captures methane emissions (CH_4), nitrous oxide emissions (N_2O) and carbon dioxide emissions (CO_2) in CO_2 equivalents. It appears that the scenario under consideration has very limited impact on the environmental indicators provided in CAPRI. Table 10 shows that average GWPT per hectare in the EU-27 actually increases, but because there is less farmland the overall GWPT is about constant.

Table 10. Environmental emissions from agriculture under reference scenario and under scenario 3 with hectare premium for legumes

	Reference scenario			**Policy scenario**		
	Total (1000 tonnes)	*Amount per ha (kg)*	*Impact on GWP (1000 tonnes CO_{2e})*	*Total*	*Amount per ha*	*Impact on GWP*
NH_3 output	2,545	13.95		2,544	13.95	
Change				-0.02%	-0.01%	
CH_4 total emissions	8,199	44.96	172,174	8,199	44.97	172,171
Change				0.00%	0.01%	0.00%
N_2O Total emissions	681		210,973	681		210,973
Change				0.00%		0.00%
Global warming potential (GWPT)	383,147	2,101		383,144	2102	
Change				0.00%	0.01%	

At regional level the development of the Global Warming Potential can be quite different from the EU-27 average (Map 8). The increase in Global Warming Potential in Poland, Denmark, southern Italy, southern Portugal and parts of Belgium, in particular, can be explained by the increased cattle herd, which leads to CH_4 emissions. That increase in turn is explained by (a) the reduction in feeding costs and (b) the relatively large share of feeding costs in total revenue and total production cost, including calculated costs for fixed inputs.



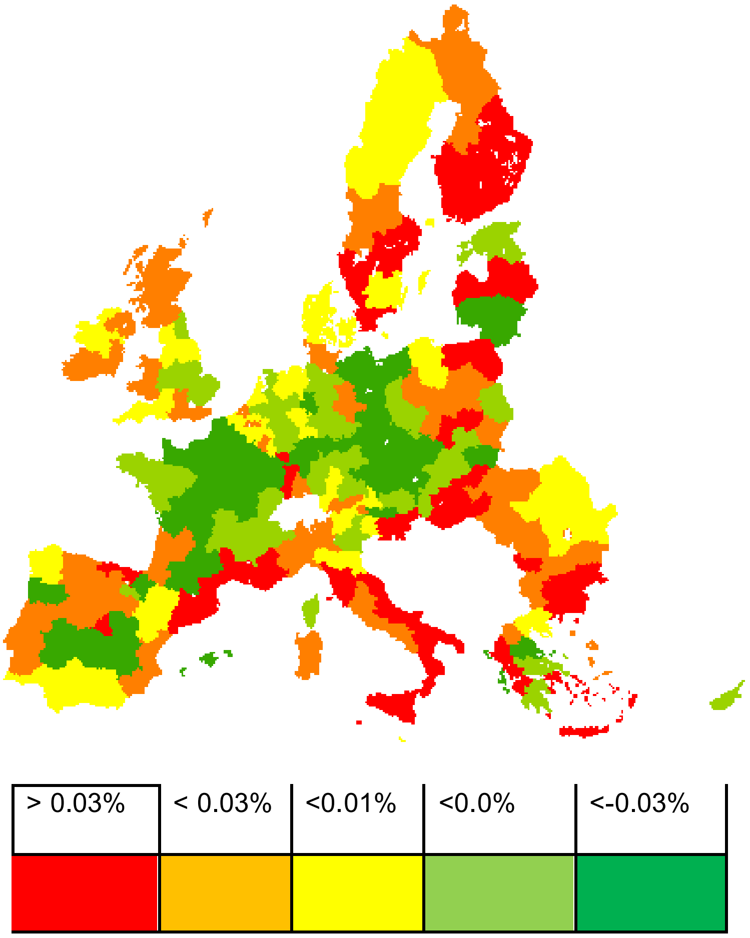
Map 8. Global warming potential per ha: % change in policy scenario compared to reference

Other explanations are the decrease in agricultural land (due to expansion of built-up land and – in some countries – conversion to forest or nature) and the increased intensity of production on remaining agricultural land (changes in cropping plan), which offset the positive impact of the increased acreage of pulses and soybeans on global warming potential. For example, the share of grain maize and other cereals increases relatively sharply in some regions in the South of France, namely Languedoc-Roussillon and Provence-Alpes-Côte d’Azur. This more intensive use of remaining agricultural land is also stimulated by an upward trend in field-crop prices, except pulses and soybean.

Table 11 shows the average impact on gross nutrient balances in the EU-27. The impact on the total nutrient surplus per ha is about zero. With respect of the nitrate (N) balance this is especially explained by the increased input of N through biological fixation. Input of phosphate (P_2O_5) and potassium (K_2O) with mineral fertiliser increases due to, on average, more intensive use of agricultural land: e.g. extensive grassland is replaced by grain legumes and intensive grassland. Map 9 shows the regional impact on nitrogen surplus per ha. The spatial pattern of the impact is comparable to that of global warming potential.

Table 11. Gross nutrient balance in 2020 in reference (kg per ha) and changes due to scenario 3 (%)

	Reference scenario			**Policy scenario**		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Input with mineral fertilisers	58.5	17.9	19.0	-0.1%	0.1%	0.1%
Input with manure (excretion)	52.1	27.3	54.4	0.0%	0.0%	0.0%
Input with crop residues	34.6	15.7	38.8	0.0%	0.0%	-0.1%
Biological nitrogen fixation	6.8			1.8%		
Atmospheric nitrogen deposition	11.8			0.0%		
Nutrient export with crop products	107.3	47.2	84.9	0.1%	0.0%	0.0%
Surplus total	56.5	13.7	27.3	0.0%	0.0%	0.0%



Map 9. Changes in nitrogen surplus per ha (%) in policy scenario compared to reference

5.3.3 *Market effects*

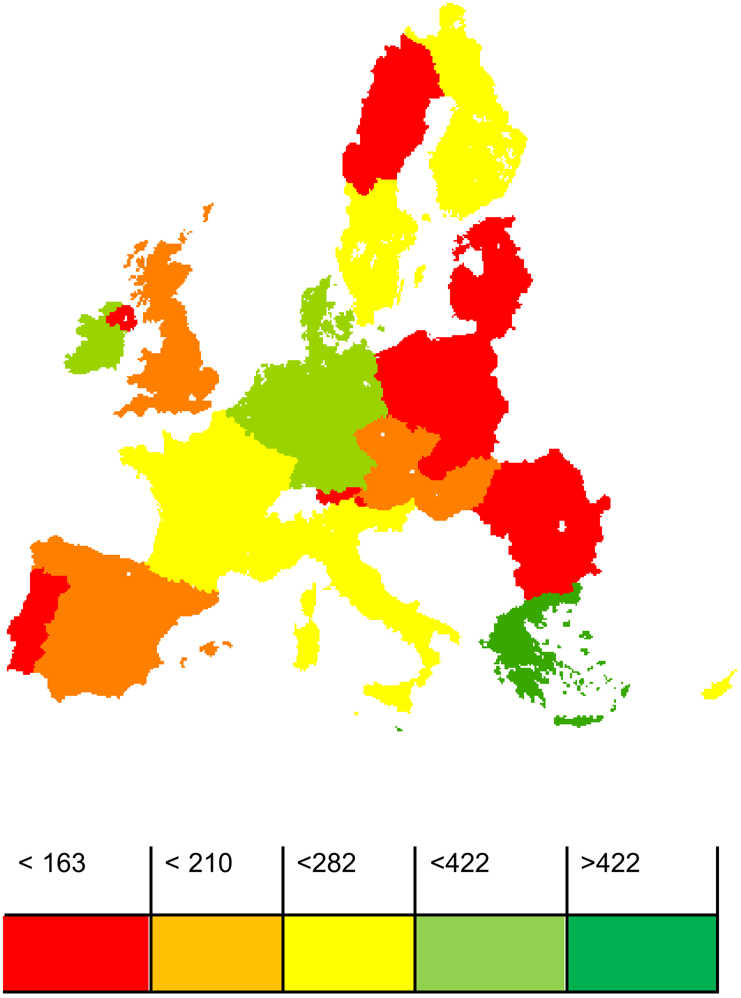
Market balances of soya seed, pulses and soya cake are presented in Table 12. This table shows that the increase of net production exceeds the increased human consumption, processing and feed use. As a result imports decrease and exports increase. Average prices of soybeans and pulses in the EU-27 decrease with about 4% and 3% respectively. These decreases are much stronger in the 12 new member states (5-6%) than in the 15 older members (2-3%).

Table 12. Market balance of soya seed and pulses in reference scenario and under scenario 3 with premium to protein crops

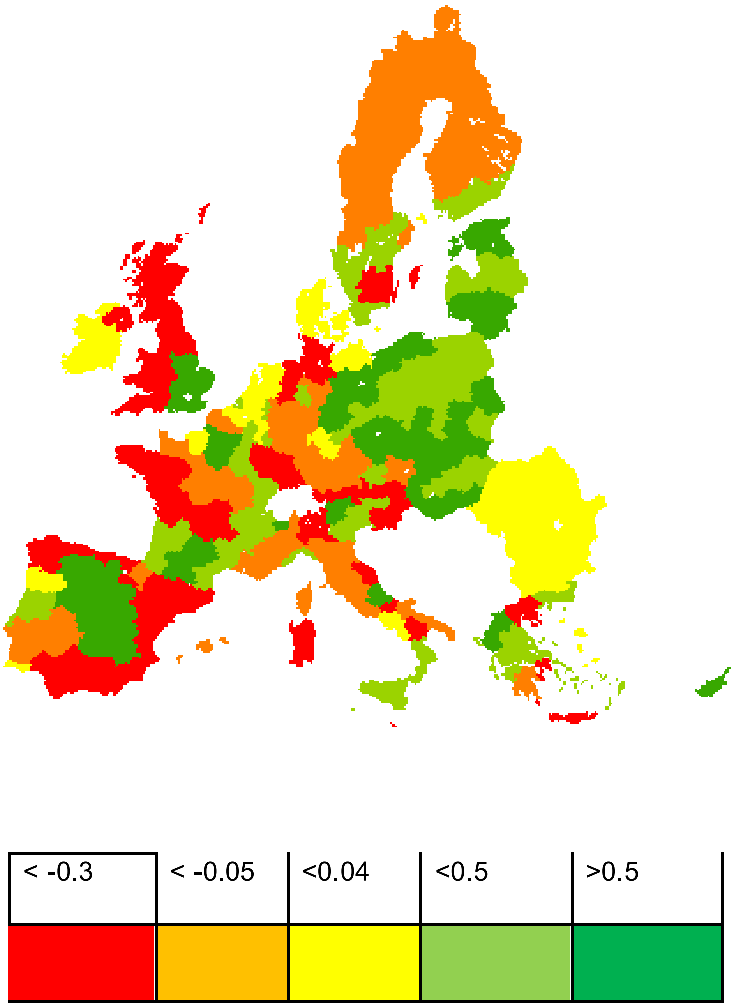
	Reference scenario **(‘000 tonnes)**			**Policy scenario** **(% change compared to reference)**		
	Soya seed	*Pulses*		*Soya seed*	*Pulses*	
Net production	1,237	2,290		11.1%	12.8%	
Human consumption plus losses	98	1,185		-0.2%	1.2%	
Human consumption plus losses, quality corrected	98	1,185		0.2%	0.8%	
Processing	14,833			-0.2%		
Feed use	845	1,885		-0.3%	4.2%	
Armington quality corrector	1	1		0.0%	0.0%	
Imports	14,720	1,383		-0.8%	-7.4%	
Exports	181	603		30.2%	16.3%	
Net trade	-14,540	-780		-1.2%	-25.7%	

5.3.4 Income effects

One obvious income effect of the legume premium is on farmers the legume premium. The payment per hectare for grain legumes, as calculated according to the scenario described in Chapter 3, ranges from about €70 in Latvia to over €425 in Greece (Map 10). It should be noted that this payment is provided on top of the direct farm payment in Pillar 1. The introduction of these payments also leads to a redistribution of total Pillar 1 payments (direct farm payments and hectare premiums) per region. This is presented in Map . For example, in the UK the total Pillar 1 payments increase in the southeast at the expense of the rest of the country. It is also possible that total Pillar 1 payments increase in all regions of a member state. This is explained by a better use of the available payment rights after introducing this scenario.



Map 10. Premium for legumes (euro per ha)



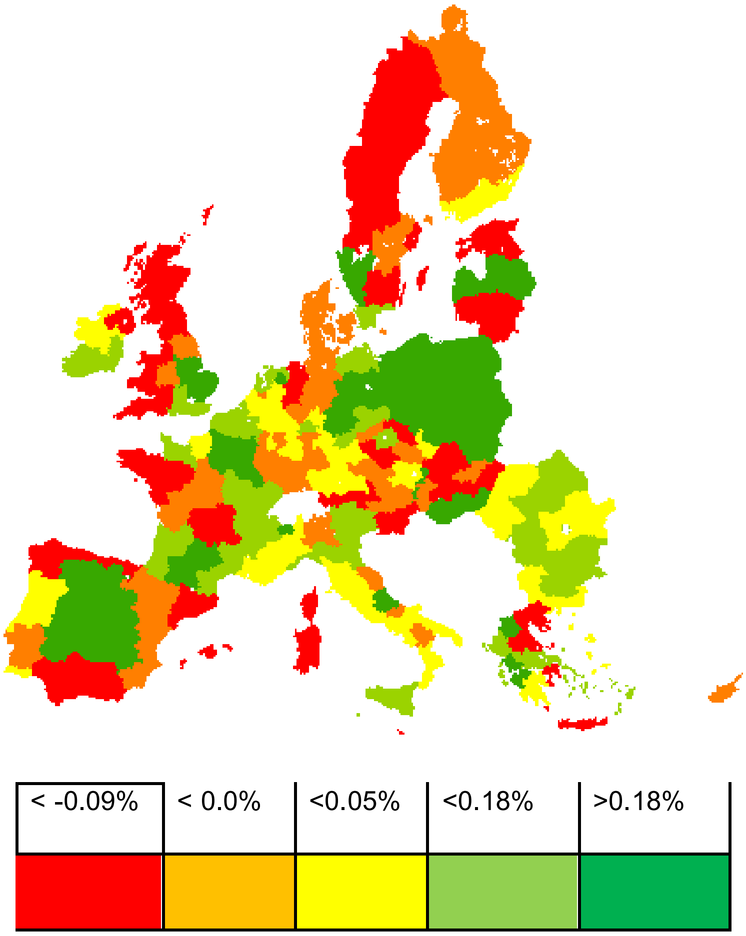
Map 11. Total Pillar 1 payments per region (% change compared to reference)

However, farmers' incomes are not only affected by these payments, but also by changes in output prices (lower for legume crops, slightly higher for other products). Production costs are also affected, as less fertiliser is needed where legumes are grown. On average, farmers' incomes increase only by 0.08%, or an aggregate amount of 153 million euro (Table 13). As explained above, the impact at regional level varies, with increases in some regions and decreases in others (Map 1).

CAPRI also calculates the effect on other sectors of the economy (e.g. lower output of fertiliser), the cost of the policy to the taxpayer, and the effect of changes in prices on consumers. All of these effects are shown in Table 7, for the EU-27 as a whole. The net effect on the economy of the EU-27 as a whole is a very slight increase of about 139 million euro, or 0.01%.

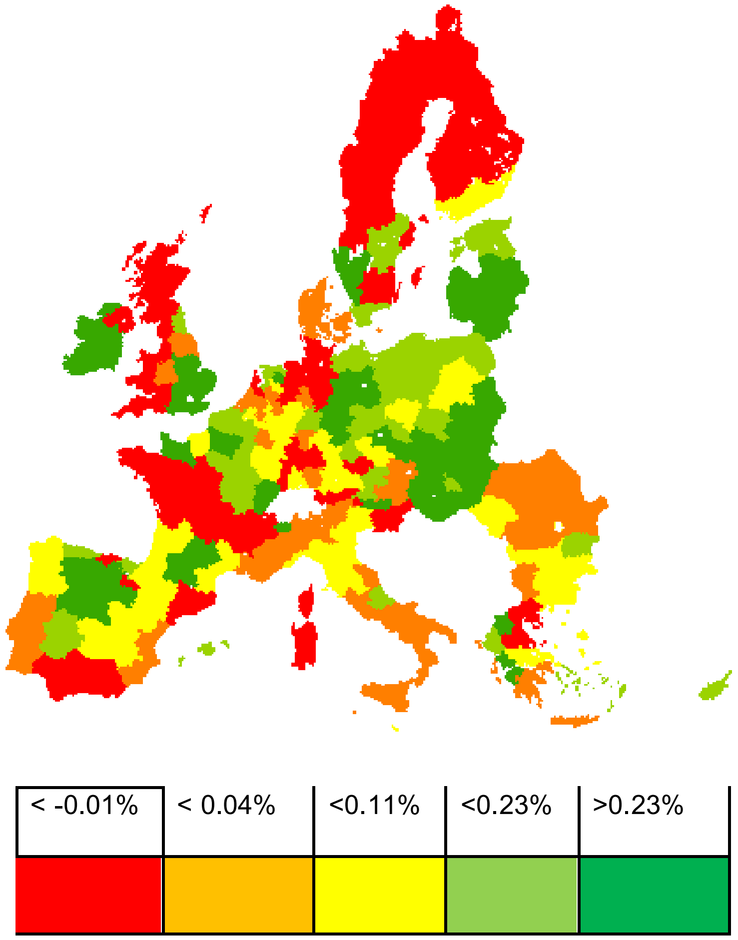
Table 13. Income effects of legume premium, compared to reference scenario

GDP component	**million euro**
Consumers	36.26
Agricultural income	153.15
Income remaining sectors minus cost to taxpayers	-50.15
Total	**139.26**

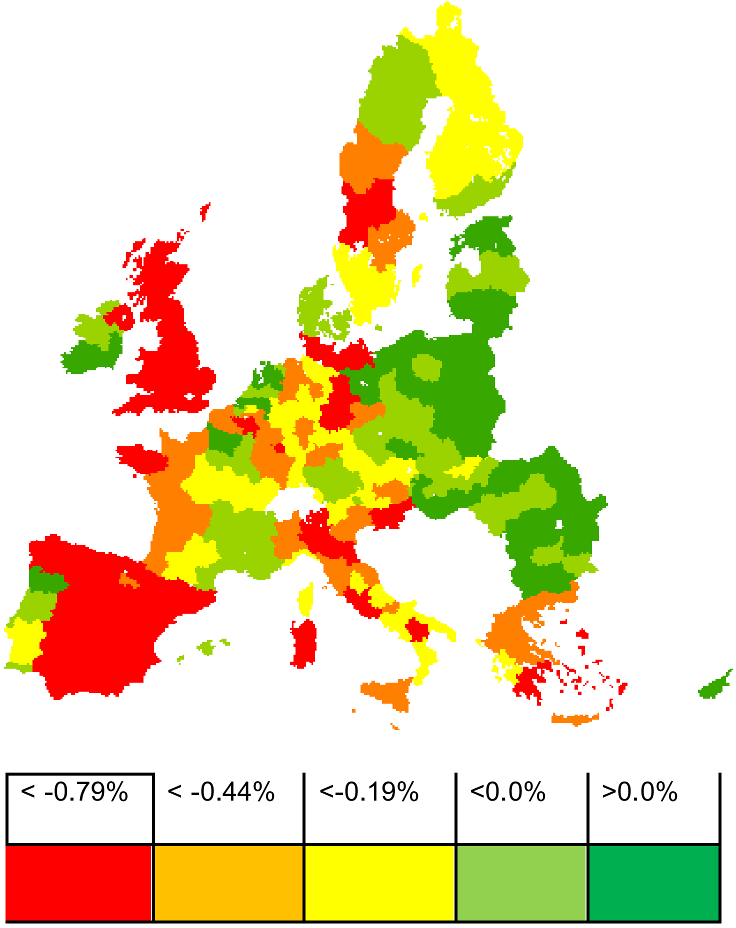


Map 12. Farm income per NUTS2 region.
Percentage change from scenario 3 compared to reference

Average impacts at regional level hide the impact at farm level. To get an idea about the average impact on farm level, Map and Map show the impact on average income per hectare for arable crops and grassland respectively. In most regions arable farms will gain, although this depends on the share of protein crops in the cropping plan. For example, the share of pulses in total UAAR is relatively low in Brittany, hence the premium is offset by the decrease in direct farm payment. Farms with mainly grassland lose income in almost all regions. This is of course the result of the partial shift of direct farm payments from pasture farmers to producers of grain legumes. This decrease in direct farm payment per ha is only partly offset by higher revenues and structural changes.



Map 13. Income from arable farming (€/ha):
% change in legume premium scenario compared to reference



Map 14. Income grassland activities (euro per ha).
Percentage change in legume-premium scenario compared to reference

5.3.5 Conclusions

The overall impact of this scenario is quite limited. There is a sizeable effect on the area of land under legumes, but it is achieved at a cost of several hundred euros per hectare, and even then it is not sufficient to achieve a level of legume cultivation comparable to what it was in the past.

Moreover, the model shows that the limited positive consequences of a policy such as a legume premium may well be nullified by what happens elsewhere in the agricultural sector: intensification of crop production and the increase of livestock herds due to cheaper feed.

5.4 Legumes included in Ecological Focus Areas

5.4.1 Land-use effects

Whereas in the grain legume premium scenario, discussed in the previous section, the farmer must grow legumes in order to benefit from the premium, in this scenario the regional farmer has the choice between various options of realizing the Ecological Focus Area. This leads to a much smaller effect on the cultivation of legumes than in the previous scenario (Table 14): the area under legumes increases by only 3.4%, as compared to 12% under legume premiums. This is because the farmer is likely to prefer the option of set-aside land and fallow in many cases. Hence, these increase by almost 3 million hectares, partially at the expense of arable crops and partially through a reduction in temporary grassland.

Table 14. Land use in 2020 in the reference scenario and changes due to scenario 4 (all data are in thousands of hectares)

	EU-27		**15 old member states (pre-2004)**		**12 new member states (2004-07)**	
	Reference scenario	*EFA scenario*	*Reference scenario*	*EFA scenario*	*Reference scenario*	*EFA scenario*
	thousand hectares					
Utilised agricultural area	182,345	36	128,196	37	54,149	0
Arable land	124,182	1,033	83,863	829	40,319	204
Pasture	58,163	-997	44,333	-793	13,829	-204
Obligatory uncropped (formerly set-aside)	2,786	2,239	2,786	1,868	10	371
Other fallow land	5,854	700	3,374	358	2,480	342
Pulses	1,022	35	836	26	186	9
Soya	516	17	194	12	322	4
Remaining arable crops (cereals, etc.)	114,004	-1,958	76,673	-1,435	37,322	-522

5.4.2 Other effects

The environmental impact of this scenario is similar to that described for the previous scenario, but much smaller since it leads to a smaller increase in legume cultivation. The same is true for market effects.

The differential effect of the EFA scenario as compared to the hectare premium for grain legumes is easily explained because the difference between non-compliance and compliance costs to the farmer, which can be seen as a premium on growing legumes (since legumes can fulfil the EFA requirement), is much lower than in the previous scenario. They are low because the regional farmer could also choose to increase fallow land, reducing more marginal arable crops or temporary grassland.[68]

The differences in performance between old and new member states, also shown in Table , are not very large: 4% increase in legumes in the former, 3% in the latter. There is a difference in the increase in fallow and set-aside: new member states have little set-aside land at present, so the projected increase there is large. For fallow land the opposite applies. However, the changes in the total of fallow and set-aside are similar to those in old member states: 29% increase in the former, 36% in the latter.

The marginal compliance costs (being the difference between the cost of non-compliance and compliance) per NUTS2 region of the EFA restriction, as defined and implemented in CAPRI, are shown on Map . These costs are lowest in regions with relatively low Pillar 1 direct farm payments and relatively high share of high-margin crops in the regional cropping plan (and vice versa). Marginal compliance costs are highest in northwestern Europe, especially due to relatively high direct farm payment per ha. Relatively low compliance costs apply in Spain, Portugal, Austria, Finland, Lithuania, Romania and Bulgaria, and also in parts of the UK, Sweden, Germany, Poland, Italy and Greece. In some region, the EFA restriction is fulfilled by decreasing extensive and low-margin roughage production for beef cattle; beef production then also decreases. This is the case in Tirol and Vorarlberg (both in Austria), Galicia (Spain), and in the Greek regions of Central Macedonia and Attica. This shows the interrelation between different farm types as implicitly included in the regional farm approach. After a few years of adjustments to the new (policy) situation, this could also occur in reality.

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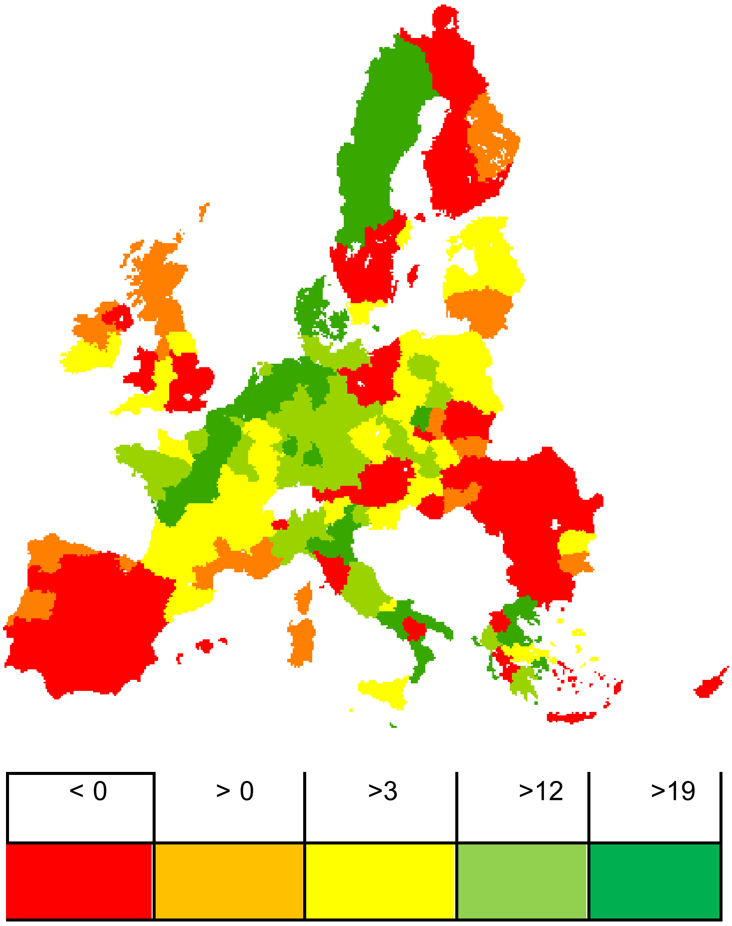
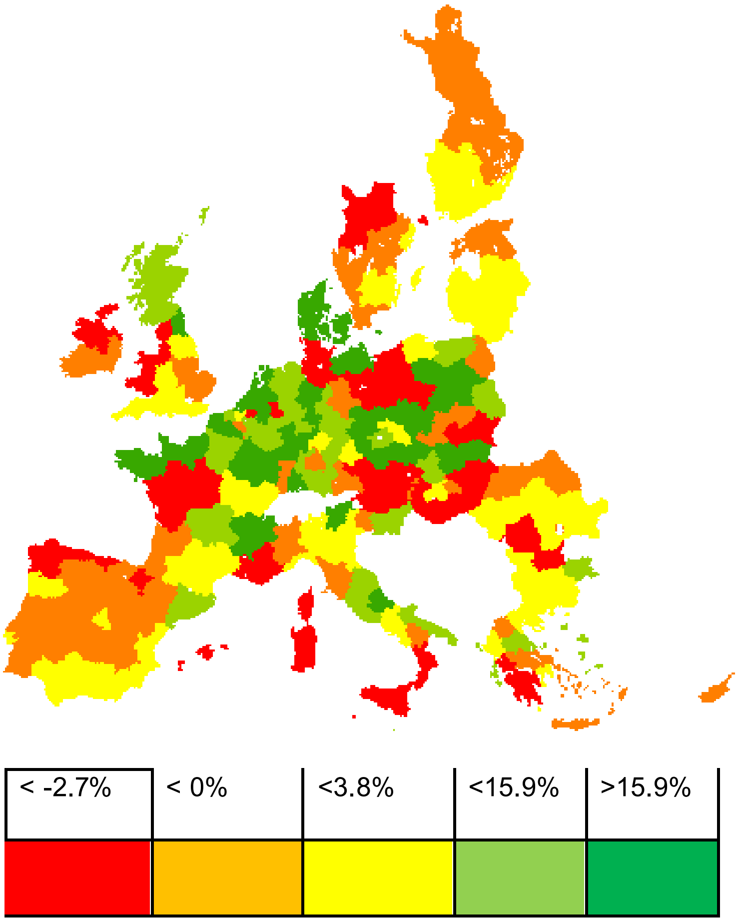
[68] This is probably less feasible at specialised arable farms. However, CAPRI’s regional approach (see Chapter 4) means that, since each region is treated as a farm, individual farm structure is not taken into account and the cropping plan is optimised at regional level, assuming interaction between individual farms. Hence, the arable farmer could, after a certain time period with structural change, also use marginal land of the grassland farmer to fulfil his own EFA requirement.



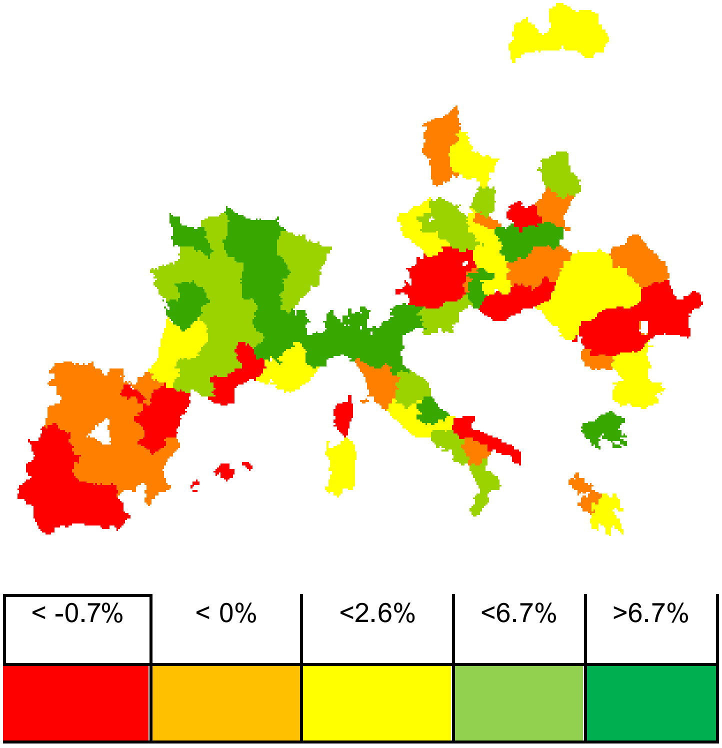
Map 15. Marginal compliance costs of EFA restriction (euro per ha)

Map and Map show the impact on acreage of pulses and soybeans respectively. The increase in acreage of pulses is relatively large in, for instance, the Netherlands and Denmark. Here the marginal compliance costs, viewed as a premium on growing pulses, are relatively high. The impact on acreage of pulses in these countries is strengthened by a relatively high supply elasticity (due, among other factors, to a low share of pulses in the regional cropping plan in the reference scenario). Decreases in acreage of pulses can also be observed. This is explained by the decrease in prices of pulses and increased costs of land, which more than offsets the implicit subsidy on pulses. This happens, for instance, in northwestern Spain.

Concerning soybeans, the relatively largest increase in acreage can be found in France and in Italy. Again, the impact is a mix of marginal compliance costs (what is the initial direct farm payment and what are the alternatives for increasing acreage of soybeans) and supply elasticities of soybean.



Map 16. Changes in acreage of pulses in EFA scenario (% change compared to reference)



Map 17. Changes in acreage of soybean in EFA scenario (% change compared to reference)

5.4.3 Conclusions

Allowing arable farmers the possibility to grow legumes as a fulfilment of the EFA requirement is likely to have only a limited impact on the cultivation of these crops. Alternative ways to comply with the EFA policy will probably prove less costly and hence more attractive. The environmental and other impacts of the policy will therefore also be smaller than under the legume premium scenario.

5.5 Incentives for a shift in consumption from meat towards vegetable protein

Whereas the two preceding scenarios have a direct effect on land use, the primary effect of this scenario will be on the market for animal and vegetable proteins. Hence we discuss this aspect first, followed by the consequences for legume cultivation.

5.5.1 Market effects

The average tax on meat consumption in the EU-27 equals about 7% of the average margin between producer and consumer prices of meat in the EU-27. The corresponding subsidy on human consumption of pulses equals about 50% of the average margin. Meat consumption in the EU-27 decreases by about 1.1 million tonnes, while human consumption of pulses increases by 865,000 tonnes.

Table 15 shows that the subsidy of about 50% of the margin between producer and consumer prices results in a decrease in the consumer price of pulses of about 855 €/tonne or -34% and an increase in the producer price of pulses of about 14 €/tonne or about 4.9% as compared to the reference, so most of the subsidy is captured by the consumers. With respect to meat products the impact on producer prices and consumer prices is much more limited. That is also understandable as the tax is relatively low. It is found that between 15% (poultry meat) and 35% (beef) of the tax on meat consumption is translated into decreasing producer prices.

Table 15. Producer and consumer prices in reference scenario and in the consumption change scenario in 2020 (EU-27)

	Reference		**Consumption change (scenario 5)**			
	Producer price	*Consumer price*	*Producer price*	*Consumer price*	*Producer price*	*Consumer price*
	€/t	*€/t*	*Absolute difference with reference (€/t)*		*Percentage difference with reference*	
Pulses	278	2518	14	-855	4.9%	-34.0%
Beef	3408	6798	-84	159	-2.5%	2.3%
Pork meat	1592	4436	-55	157	-3.4%	3.5%
Sheep and goat meat	5388	5747	-51	138	-0.9%	2.4%
Poultry meat	1578	4668	-16	94	-1.0%	2.0%

The change in the consumption of individual meat products per member state and in the consumption of pulses per member state is determined inside the model, based on changes in marginal revenue and marginal costs; these are also driven by price differences between member states and corresponding changes in trade. Table 16 shows the impact on market balances at the level of the EU-27. Human consumption of pulses increases by more than 70%. On the other hand, net production increases by only about 3%. The market balance of pulses in the EU-27 is mostly maintained by decreased feed use, increased imports and decreased exports.

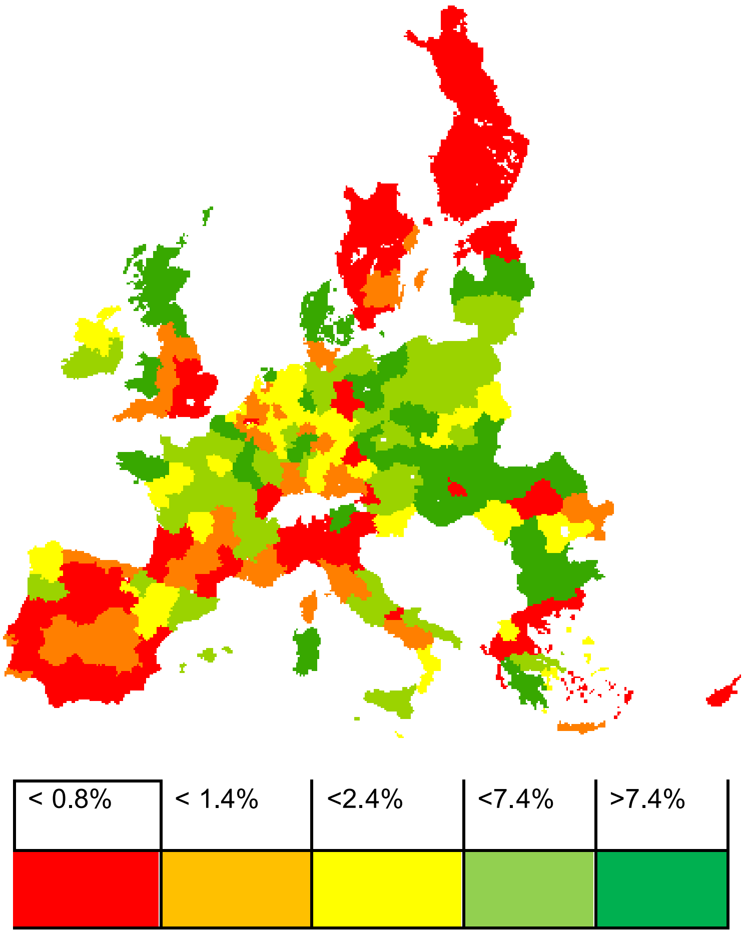
With respect to meat products it appears that the tax on meat consumption mainly affects the consumption of pork, which is reduced by 4%. Again the impact on trade exceeds the impact on own production. The latter is relatively limited.

Table 16. Development of market balances under the meat tax scenario, differences with reference scenario in 2020

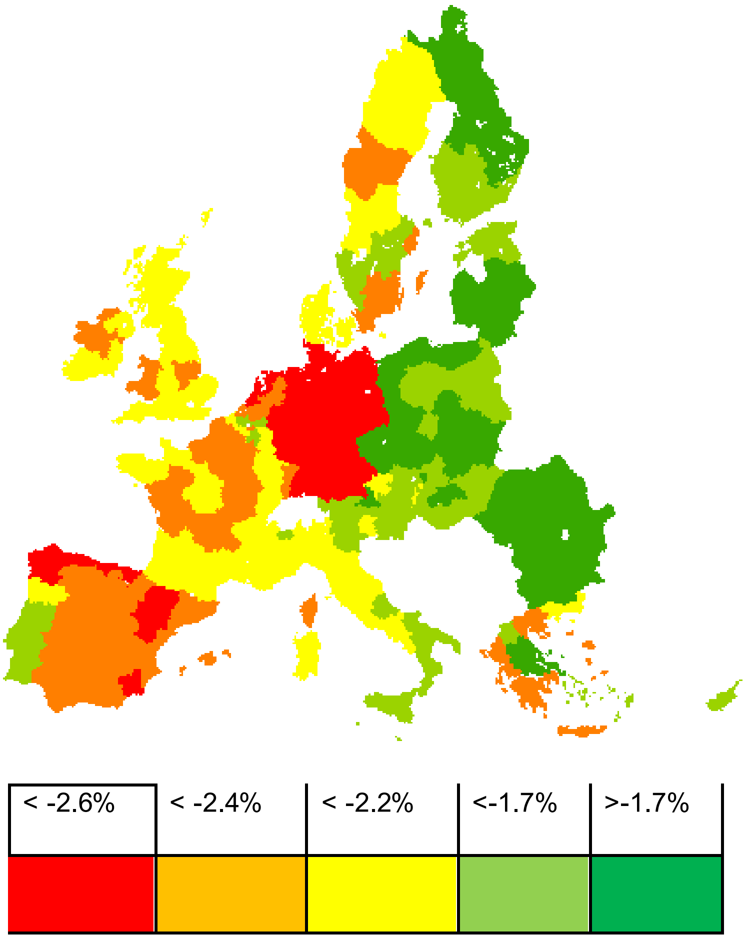
	Difference, 1000 tonnes					
	pulses	*beef*	*pork*	*mutton and goat meat*	*poultry meat*	*total meat*
Net production	67	-36	-562	-1	-95	-693
Human consumption	858	-69	-862	-9	-142	-1083
Feed use	-169	0	0	0	0	0
Imports	518	-27	-29	-2	-9	-67
Exports	-105	7	271	7	39	323
Difference, percentages						
Net production	2.9	-0.5	-2.4	-0.1	-0.7	-1.5
Human consumption	72.4	-0.9	-4.0	-0.8	-1.1	-2.5
Feed use	-8.9					
Imports	37.4	-5.4	-3.0	-0.6	-1.6	-2.9
Exports	-17.4	1.6	9.8	5.6	3.5	7.3

5.5.2 Land use effects

Map below shows the impact on acreage of pulses in the crop-based protein scenario. The impact ranges from an increase of less than 1%, e.g. in Finland, southern Britain, southern France and northern Italy to an increase of more than 7% in Scotland, Brittany and Eastern Europe. Map 19 shows the impact on the numbers of fattening pigs. Pig production decreases especially in Western Europe, less in Eastern Europe. Beef production decreases particularly in the Netherlands, Belgium, Germany, Denmark and Spain, although only by about 1%.



Map 18. Development of acreage of pulses in meat tax scenario
(% change compared to reference)



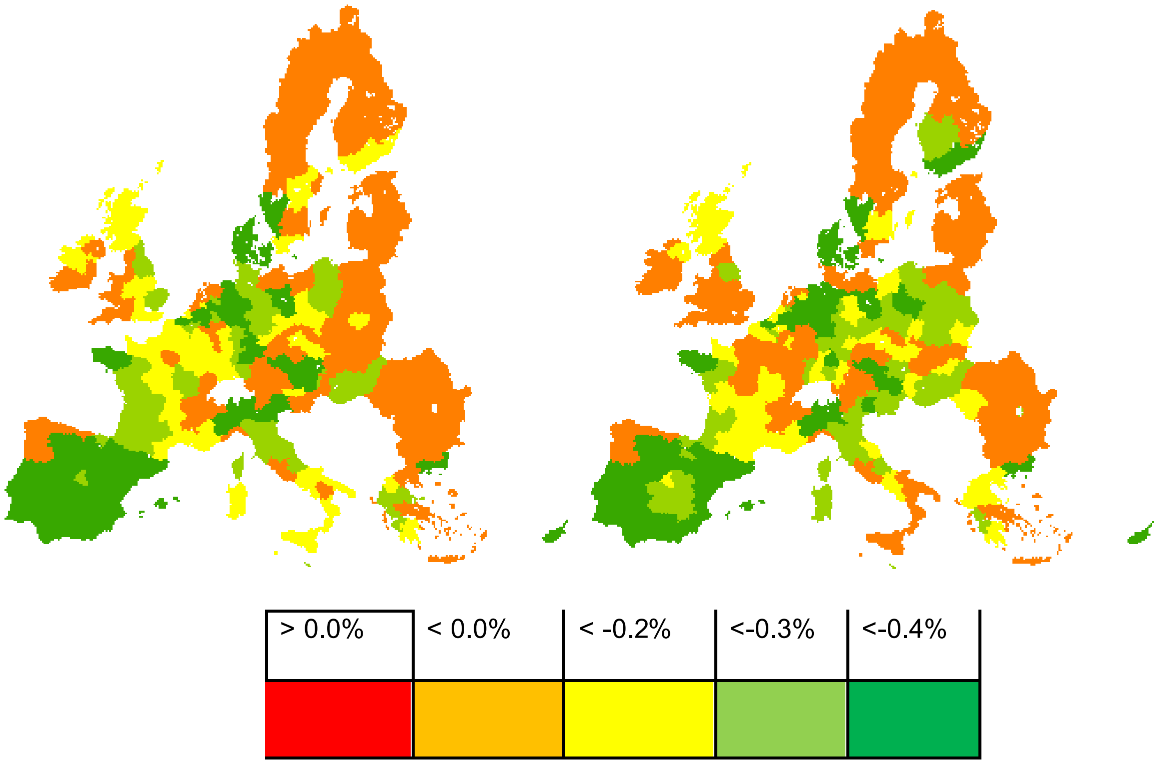
Map 19. Development of number of fattening pigs in meat tax scenario
(% change compared to reference)

5.5.3 Environmental impact

Total global warming potential decreases compared to the reference by about -0.4%. The impact per ha is slightly less. This is due to agricultural land being taken out of production: fewer animals require less feed, hence a lower land demand for feed production.

Table 17. Changes in average environmental indicators in the EU-27 under the consumption change scenario (% compared to reference)

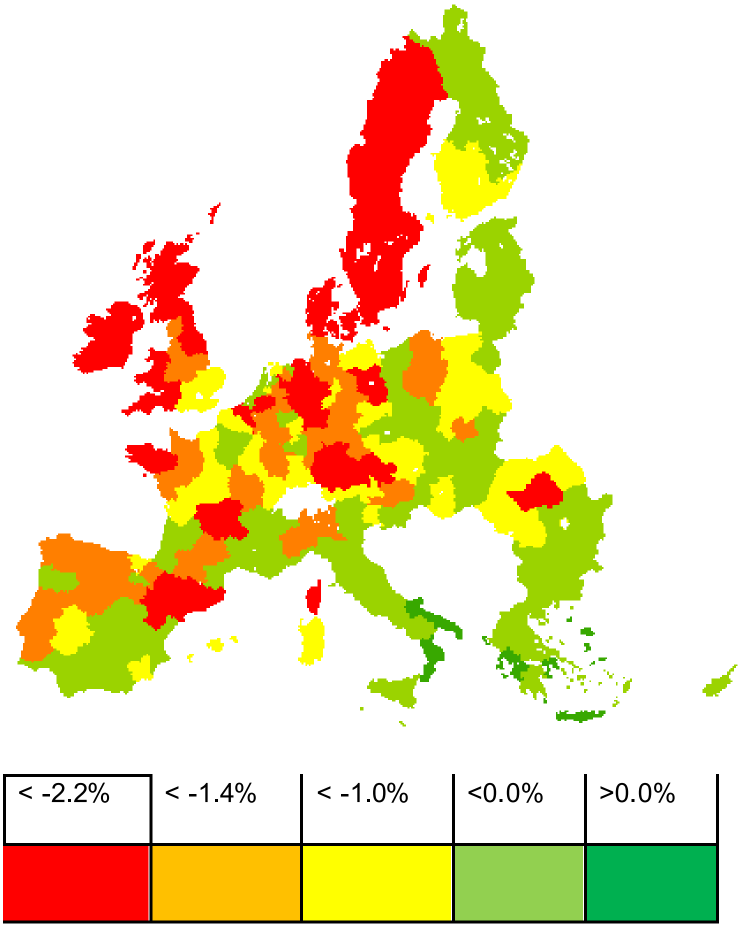
	Total	Amount per ha
Ammonia output	-0.67%	-0.62%
CH_4 total emissions	-0.43%	-0.38%
N_2O total emissions	-0.36%	
Global warming potential	-0.39%	-0.34%



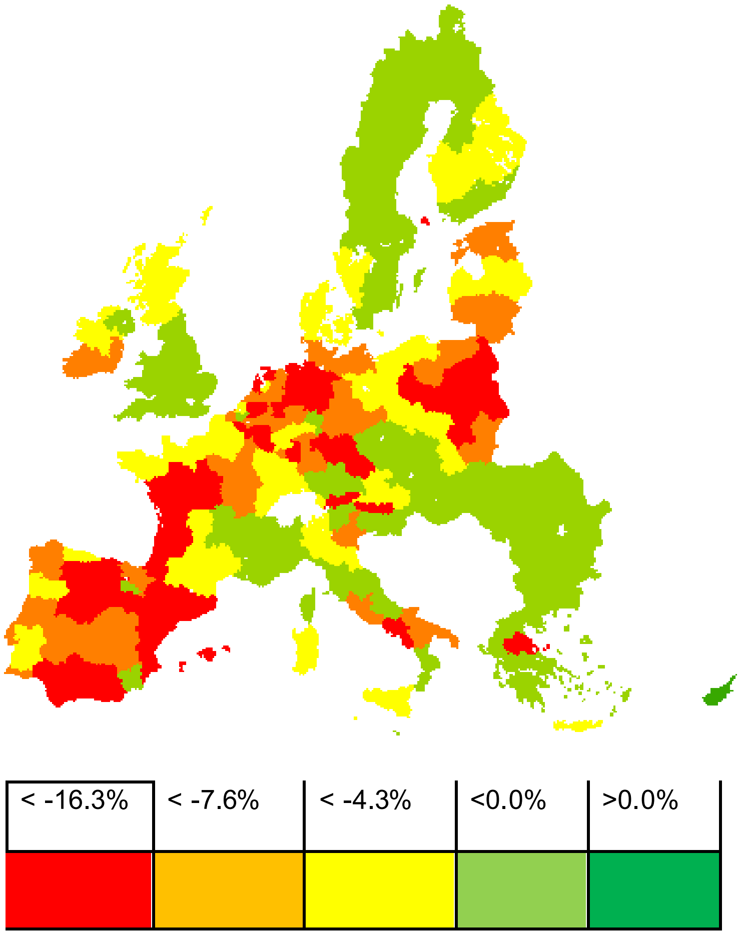
Map 20. Development of GWPT per ha (left figure) and nitrogen surplus per ha (right figure), % change compared to reference

5.5.4 Income effects

Map shows the impact on regional agricultural income. Overall that impact is negative. The negative income effect is highest in regions with a relatively large share of income from meat activities and a relatively low share of income from pulses, such as Ireland, the UK, Sweden, Denmark, and parts of Belgium, Germany and France. The impact on regional income in the Netherlands is relatively small, as large part of agricultural income in the Netherlands comes from dairying and horticulture. However, the impact on agricultural income can be large on individual farm types. Map shows the impact on average gross margin per head for beef farming. The impact appears especially large in the Netherlands, Belgium, Spain and parts of France and Poland.



Map 21. Development of regional agricultural income, % change compared to reference



Map 22. Development of average gross margin per head for beef farming, % change compared to reference

5.5.5 Conclusions

This scenario leads to a larger increase in the cultivation of legumes than the EFA scenario, but less than the legume premium scenario.

- The scenario with a tax on meat consumption and a subsidy on consumption of vegetable protein especially affects imports and exports of meat and pulses.
- The positive impact on the environment is limited and might be dampened by a relative increase in concentration of agricultural production and land use intensity;
- Agricultural income decreases, which provokes further increase in scale of the production of individual farms. This is however outside the scope of CAPRI.

5.6 Compulsory inclusion of forage legumes in grass swards

5.6.1 Land use effects

The scenario supposes that it will be compulsory to have clover cover at least 25% of total pasture land in each member state – although not necessarily in each region. This means that regions which are close or above this 25% do not need to adjust their technique and production plan. However, where the percentage clover is low, a relatively large acreage of grassland will have to be intersown with clover to fulfil the policy requirement.

For example, for Ireland the average yield for grassland under the policy scenario is calculated as:

$$\text{AverageYieldGrassland(New)}= (0.25/0.22)*\text{YieldGrasslandWithClover}+(1-(0.25/0.22))*\text{YieldConventional} \qquad (1)$$

Where 0.25 is the obligatory fraction of clover in grassland, and 0.22 is the existing fraction. The values of YieldGrasslandWithClover and YieldConventional can be found in Table 1 (Chapter 3, section 3.6). The yield shift is then calculated as:

$$\text{YieldShift}= \text{AverageYieldGrassland(New)}/\text{YieldConventional} \qquad (2)$$

Permanent grassland in CAPRI is equally split between intensive and extensive grassland. It is assumed that the yield shift on intensive grassland is 150% of the average yield, while the yield shift on extensive grassland is 50% of the average yield shift. This is consistent with the finding in the literature that the impact of clover on yields in grassland is larger on intensively managed grassland.

The scenario allows regional differences in yield changes, related to changes in percentage clover (as presented in Table 1). However, the technical data in that table are more or less point estimates, and there appears to be quite some uncertainty around these points.

Not included in the modelling exercise are changes in the net energy and protein content of the resulting silage. As Table 1 shows, these differ per country, but the data available have insufficient geographical coverage. They are notably lacking for the southern half of Europe.

5.6.2 Environmental impact

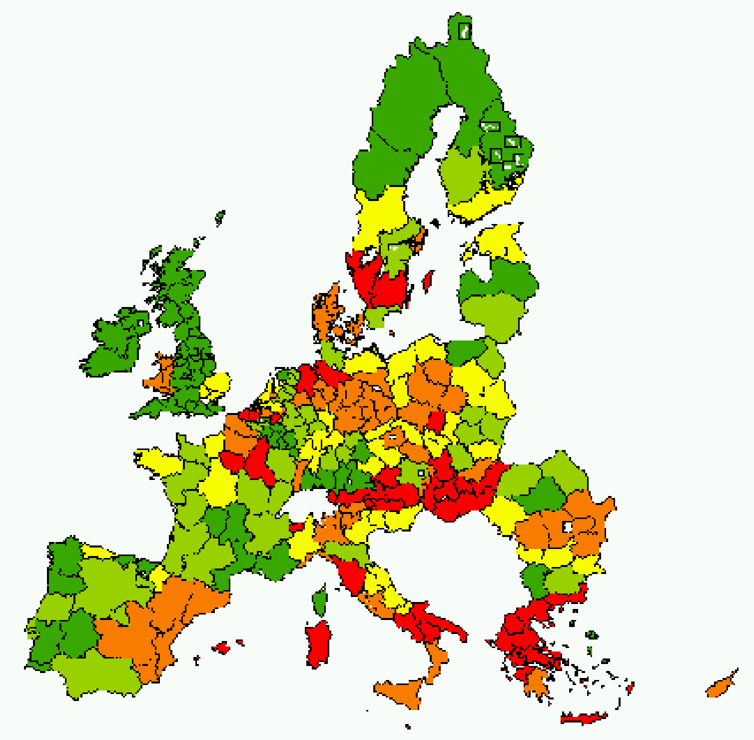
Grass-clover mixes have lower impacts on the environment compared to fertilised-grass pastures, as Table 3 indicates, particularly with respect to nitrogen. There is a favourable effect on ammonia and methane emissions, but it is not very large. The geographical variation in the effect on nitrogen surplus (Map) is considerable, and does not coincide with the impact on grassland yield, as shown in Maps 24-26 below. In

Greece, for instance, the additional cost caused by the policy is relatively small, whereas the effect on nitrogen surplus is large. In this way, the maps can be used to pinpoint regions where, on balance, the effect of the scenario is most likely to be beneficial.

However, it must be noted that in regions which already have a high share of clover in grassland, intensification of production is possible, resulting in an increased N surplus. Farmers may also increase the share of intensive and temporary grassland in the total grass and fodder area, so as to compensate for a lower yield. The model predicts that this will happen in southern Sweden, for instance.

Table 18. Changes in emissions to the environment. Percentage difference under grassland/clover scenario as compared to reference

Ammonia output	**-0.7%**
CH_4 total emissions	-1.4%
Global warming potential	-2.1%
N Input with mineral fertilizers	-15.0%
N Input with manure (excretion)	-1.2%
N Input with crop residues	-3.3%
Biological nitrogen fixation	130.8%
Atmospheric nitrogen deposition	0.0%
N export with crop products	-2.5%
N surplus total	-4.6%

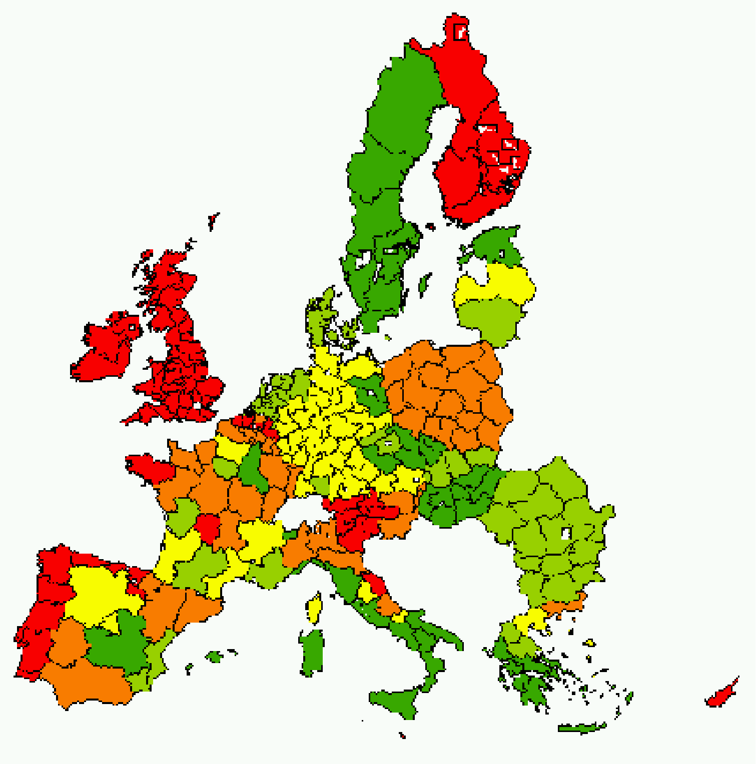


< -6.2%	< -4.2%	< -2.9%	<-1.0%	>-1.0%
🟥	🟧	🟨	🟩	🟩

Map 23. Percentage change in N surplus (kg per ha)

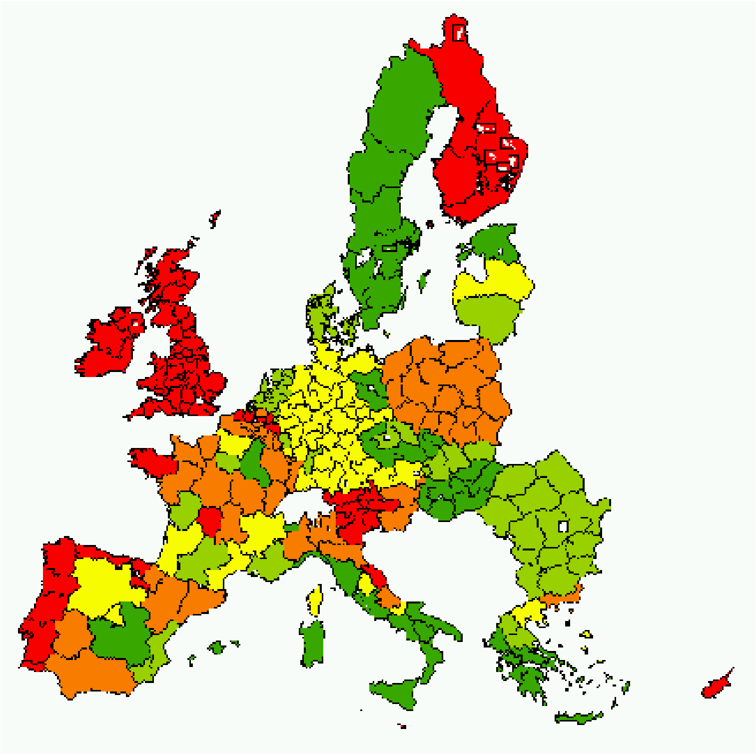
5.6.3 Income effects

Maps 24-26 show the effect of compulsory grass-clover mixes on overall yield (in dry matter) of pastures in different regions, for three different types of grassland. The countries where this effect is highest are those where the proportion of clover at present is lowest (e.g. Ireland, Portugal, Finland). Conversely, in Sweden, which already has a high proportion of clover in grassland, the policy will hardly cause any change. The effect on yield is greatest on the most intensive type of pasture. However, whereas the effect of a higher percentage of clover on the dry-matter yield is invariably negative, it is much more difficult to assess the effect on nutritional value (energy and protein), as we saw above.



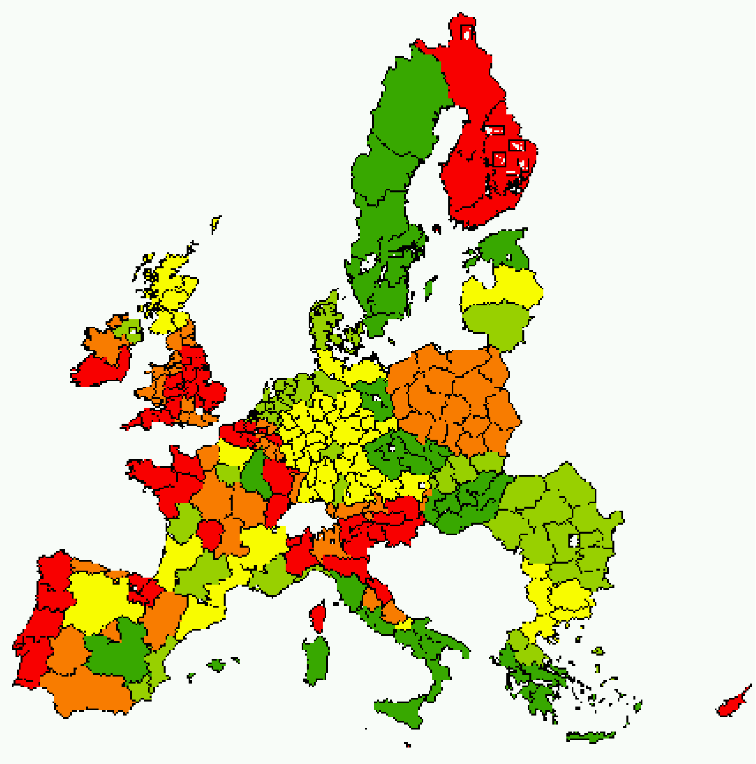
< -12.6%	< -11.4%	< -10.5%	<-5.9%	<0.0%
🟥	🟧	🟨	🟩	🟩

Map 24. Yield change intensive grassland



< -4.8%	< -3.8%	< -3.5%	<-2.0%	<0.0%
🟥	🟧	🟨	🟩	🟩

Map 25. Yield change extensive grassland



< -8.1%	< -7.5%	< -6.9%	<-4.0%	<0.0%
🟥	🟧	🟨	🟩	🟩

Map 26. Yield change temporary grassland[69]

Forecasting the impact on the cost of pasture-based livestock activities is easier, at least for the average figures shown in Table 19. Fertiliser costs decrease, but feed costs go up (due to the lower yield of grass and the resulting need to purchase additional feed), and this increase is higher than the lower fertiliser cost, so the net increase is cost is about 2.5% on average. Map shows the geographic variation in these costs. The increase tends to be higher in Western Europe, and in some regions (notably Romania) even a decrease in cost is possible. The increased feeding costs have a negative impact on profitability of the cattle herd and the number of cattle decreases. This in turn decreases the number of births and the price of young animals will increase.

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[69] Defined as grass and other fodder on arable land (OFAR).

Table 19. Average costs per type of animal feed supply in EU-27 in 2020 in reference scenario and increased clover in grassland scenario

Grassland/clover scenario (difference with reference)								
	Total costs	Fer-tiliser	Feed	Rest	Total costs	Fertilizer	Feed	Rest
Fodder on arable land	1078	472		606	-8.6%	-13.9%		-2.4%
Grassland extensive	368	144		224	-5.8%	-10.5%		-1.2%
Grassland intensive	737	406		331	-12.7%	-16.8%		-5.0%
All cattle activities	1968		1366	603	2.5%		2.0%	2.6%

Schils[70] makes a somewhat different calculation. He compares two dairy farms with the same number of milking-cows. To feed them, he uses an 18% larger area of land for the grass-clover mix than for the fertilised-grass farm. The cost of fertilizer is 82% per hectare lower on the grass-clover farm, although (since a larger area is fertilised) the aggregate cost of fertiliser is only 67% lower. The grass-clover farm spends slightly more on concentrate feeds, but this is compensated by not having to pay for silage. In his experiment the total cost of variable inputs is 7% lower on the grass-clover farm, whereas total revenue is 4% higher. The gross margin is €9,600 higher on the clover farm, but per hectare it is €400 lower, due to the larger land area needed.

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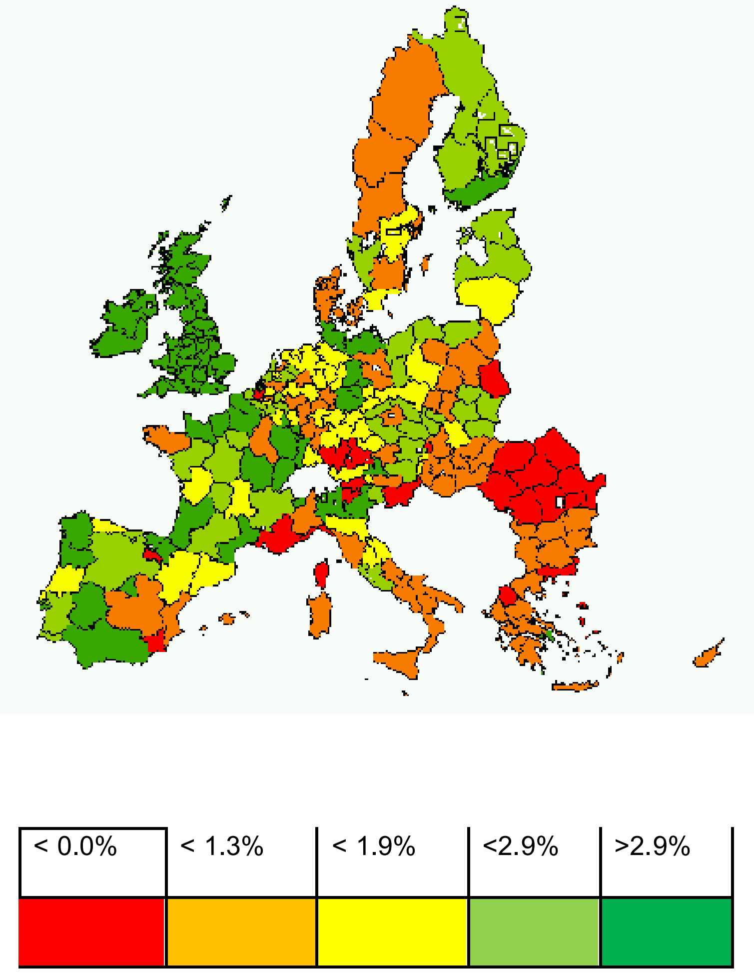
[70] Schils, R.L.M., 2002: White clover utilization on farms in the Netherlands. Wageningen University, Ph.D. dissertation, p. 113.



Map 27. Percentage change in total costs of cattle herd per region (euro per ha)

5.6.4. Conclusions

Due to the limited availability of data on forage legumes in the CAPRI database, modelling of this scenario could not be more than an exercise. Ideally, the scenario should include other forage legumes such as alfalfa/lucerne and vetches. In the real world, a forage legume policy would not confine itself to clover. Furthermore, due to the lack of technical data for different parts of Europe, it was not possible to provide reliable estimates of the impact on feeding.

- In any case, much of the economic effect will depend on how farmers would implement the policy. Ingenuity could lead to very different effects from what CAPRI predicts, as Schils' experiment has shown. Overall, the margin of livestock farming per hectare would be lower with compulsory forage legumes than without such an obligation, but the differences may well decrease as farmers adapt to the new situation – especially if fertilizer prices continue to increase.

5.7 Carbon tax

This section describes the results of the imposition of a carbon tax, with and without a compensatory subsidy on labour hours as described in section 3.7. We begin by describing the direct effect on revenue per crop and livestock type, followed by how land use and livestock numbers may change as farmers change their management in reaction to the new policy. Next comes a subsection reviewing these efffects for different regions within the EU, as the impact will be spatially diverse. Finally we discuss the environmental impact of the changes in land use and livestock, in terms of nitrate budget and global warming potential.

5.7.1 Direct impact on farm revenue

Table 20 shows the initial impact of the different taxes, premiums and subsidies on the revenue per hectare or head, i.e. before farmers change their behaviour as a reaction to said impact. The CO_2 price is here assumed equal to 72 € per tonne.

Since the proceeds of the tax are ploughed back into the sector in the form of a subsidy on labour, the impact of the tax on total revenue is rather limited; however, low-emission activities become more attractive relative to high-emission ones. The sizeable increase in revenue on potatoes, in particular, is explained by the high number of labour hours per hectare for potatoes in some Eastern European countries.

The impact on land use and number of animals in the livestock sector (see subsection 5.7.2) is mainly explained by the initial change in total revenue per activity. The total revenue per activity in the initial or reference situation is presented in the second column of Table 20. For example, without further adjustments in price, quantity and technology, the average revenue of soft wheat decreases from € 1165 per ha in the reference scenario to € 1156, a decrease of € 9 per ha (0.8%). Without the reimbursement to labour, the decrease would be about € 127 per ha, or about 11%.

In percentage of total revenue the impact of the carbon tax tax is not very different for the different types of cereals. With a CO_2 price of 72 € per tonne, the average impact of the carbon tax on total revenue ranges from about -2% on potatoes to about -17 % on grassland. In the livestock sector this range is from -2 to -3 % in poultry to about -25% for suckler cows. For low-yielding dairy cows the average impact is about -11%, while for high-yielding cows it is about -9%. This shows that a switch to dairy cows with high yield can be expected as the tax per unit of output is relatively low.

As expected, the policy has a strong positive effect on legumes, especially pulses: they use less fertiliser, lead to lower emissions in the field and attract a large premium for carbon storage. Total revenue per ha, excluding labour reimbursement, increases with about 42% and 77% for soya and pulses respectively.

Table 20. Average distribution of carbon tax payments, storage premiums and labour subsidy in the EU27 in the reference scenario, assuming emission tax of 72 € per tonne of CO_{2e}. (€ per ha or head)

	Revenue before carbon tax	Tax on fertiliser	Tax on field emissions	Carbon storage premium	Labour subsidy	Net impact (sum)
Soft wheat	1165	-57	-70		118	-9
Rye	567	-27	-39		136	70
Barley	861	-37	-51		114	26
Oats	532	-29	-46		102	28
Grain maize	1541	-56	-86		139	-3
Other cereals	753	-49	-60		92	-17
Rape seed	1359	-46	-73		116	-3
Sunflower seed	830	-25	-35		65	5
Soyabeans[1]	998	-23	-41	483	109	529
Fodder maize	1370	-25	-49		121	47
Other feed on arable land (e.g. temporary grassland)	936	-12	-96		75	-33
Grassland extensive	254	-8	-35		37	-6
Grassland intensive	586	-19	-71		37	-53
Pulses	593	-8	-16	483	89	548
Potatoes	7220	-56	-75		261	130
Sugar beet	2436	-78	-138		205	-10
Dairy cow low yield	2558		-277		199	-79
Dairy cow high yield	3870		-344		232	-112
Male adult fattening low final weight	990		-83		59	-24
Male adult fattening high final weight	1551		-176		59	-117
Heifers fattening low final weight	840		-76		42	-34
Heifers fattening high final weight	1332		-173		42	-131
Suckler cows	655		-165		114	-51
Heifers raising	1283		-194		27	-168
Pigs	144		-9		5	-3
Sows	594		-43		47	3
Laying hens[2]	20802		-494		220	-274
Poultry fattening[2]	2756		-82		520	438

[2] Per 1000 heads

5.7.2 Partial equilibrium effects

As a result of the changes in revenue per crop and per head of livestock, farmers will change their land use and livestock numbers. Table 21 shows the results for the different variants of the carbon tax described in Table 7. The total utilised agricultural area (UAA) in the EU-27 decreases, ranging from -0.1% in CarbonA1 scenario to -1.6% in CarbonB2 scenario; the latter, which does not incorporate a labour subsidy and which is based on the higher price of 18 € per tonne of CO_{2e}, yields the strongest effects. Most notable in Table 21 is the relatively strong decrease in intensive grassland and the strong increase in set-aside and fallow land. The livestock sector shows a strong decrease in beef meat activities and a switch from low-yielding to high-yielding dairy cows.

Table 21. Average (EU-27) changes in land use and livestock numbers per scenario variant (percentage difference in 2020 as compared to reference).

	Reference (1000 ha or head)	CarbonA1	CarbonA2	CarbonB1	CarbonB2
Utilized agricultural area	184,235	-0.1%	-0.4%	-0.3%	-1.6%
Cereals	54,025	-0.4%	-1.1%	-1.4%	-4.3%
o.w. Soft wheat	21,928	-0.6%	-1.1%	-2.6%	-4.5%
o.w. Barley	11,382	0.0%	-0.9%	0.0%	-3.5%
Oilseeds	12,384	0.5%	0.2%	2.1%	0.9%
o.w. Rape	6,624	-0.4%	-0.7%	-1.7%	-2.9%
o.w. Sunflower	4,516	-0.5%	-0.7%	-2.2%	-2.9%
o.w. Soya	932	11.9%	10.9%	50.6%	46.3%
Other arable crops	5,576	4.1%	3.5%	16.8%	14.5%
o.w. Pulses	1,220	19.1%	18.2%	77.1%	73.5%
o.w. Potatoes	1,528	0.3%	-0.5%	1.3%	-2.0%
o.w. Sugar Beet	1,587	-0.6%	-1.0%	-1.9%	-3.6%
Fodder activities	78,186	-0.6%	-0.7%	-2.6%	-3.1%
o.w. Fodder maize	5,261	1.2%	0.8%	-0.5%	-2.5%
o.w. Fodder other on arable land	15,383	-0.7%	-1.1%	-2.7%	-4.2%
o.w. Grass and grazings extensive	28,699	0.2%	0.3%	1.0%	1.5%
o.w. Grass and grazings intensive	28,699	-1.7%	-1.8%	-6.6%	-7.2%
Set-aside and fallow land[1]	8,166	3.4%	3.1%	13.5%	12.1%
All cattle activities	58,613	-0.7%	-1.4%	-2.1%	-4.9%
o.w. Dairy Cows high yield	10,848	-0.5%	-0.6%	-0.4%	-0.9%
o.w. Dairy Cows low yield	10,848	-0.5%	-0.8%	-0.6%	-1.7%
o.w. Beef meat activities[2]	18,009	-0.9%	-2.1%	-4.2%	-9.2%
Pig fattening	258,286	-0.2%	-0.5%	-0.5%	-2.1%
Pig Breeding	14,522	0.0%	-0.6%	-0.6%	-2.2%
Laying hens[3]	470	-0.2%	-0.1%	-0.7%	-0.4%
Poultry fattening[3]	6,446	2.4%	-0.2%	10.4%	-0.8%

[1] Set-aside and fallow land are treated as distinct categories in CAPRI, although since 2009 they are in practice the same thing.
[2] Suckler cows, male adult fattening low final weight, male adult fattening high final weight, heifers fattening low final weight, heifers fattening high final weight.
[3] Millions of heads.
Source: CAPRI

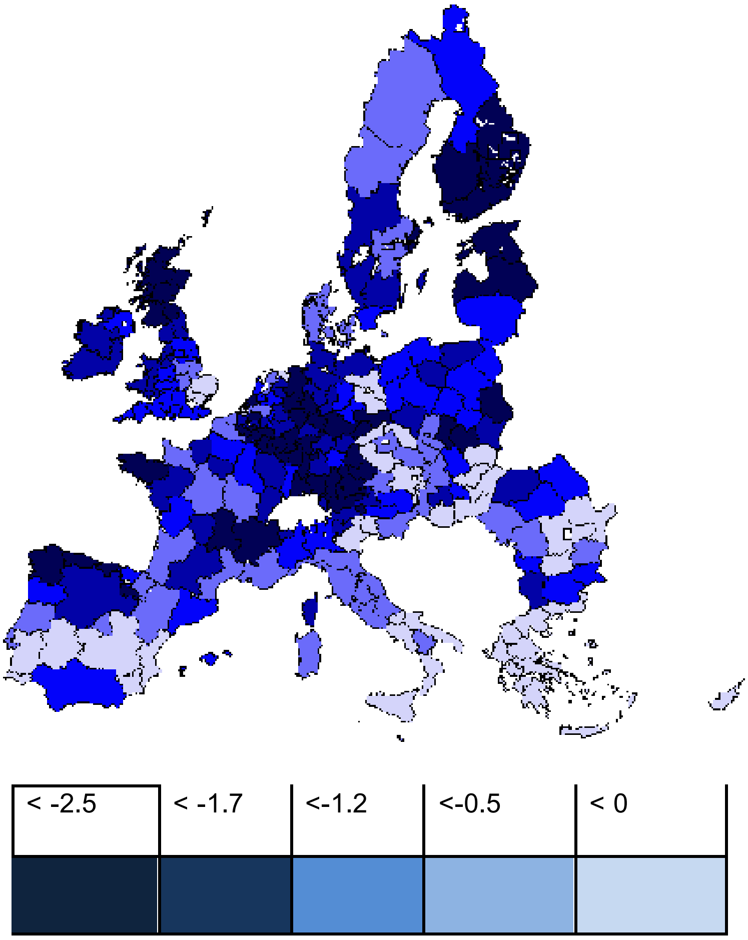
The switch from intensive to extensive grassland means a decrease in feed supply from grassland. This increases feed demand from other crops, which partially explains the limited decrease of cereals and the rather limited decrease in mineral fertiliser use on arable crops (see below). This sustained feed production from arable crops is strengthened by the switch to high-yielding animals. Also, the strong increase in set-aside and fallow land stimulates more intensive production systems on remaining crops.

Higher prices of cereals partially compensate for the carbon-tax payments. Other ways to save on tax payments is to decrease livestock production, decrease the UAA, increase fallow land, and switch from intensive to extensive grassland.

5.7.3 Regional variation in impact

Map 28 shows that the decrease in agricultural land use by region can be quite different from the EU-27 average.

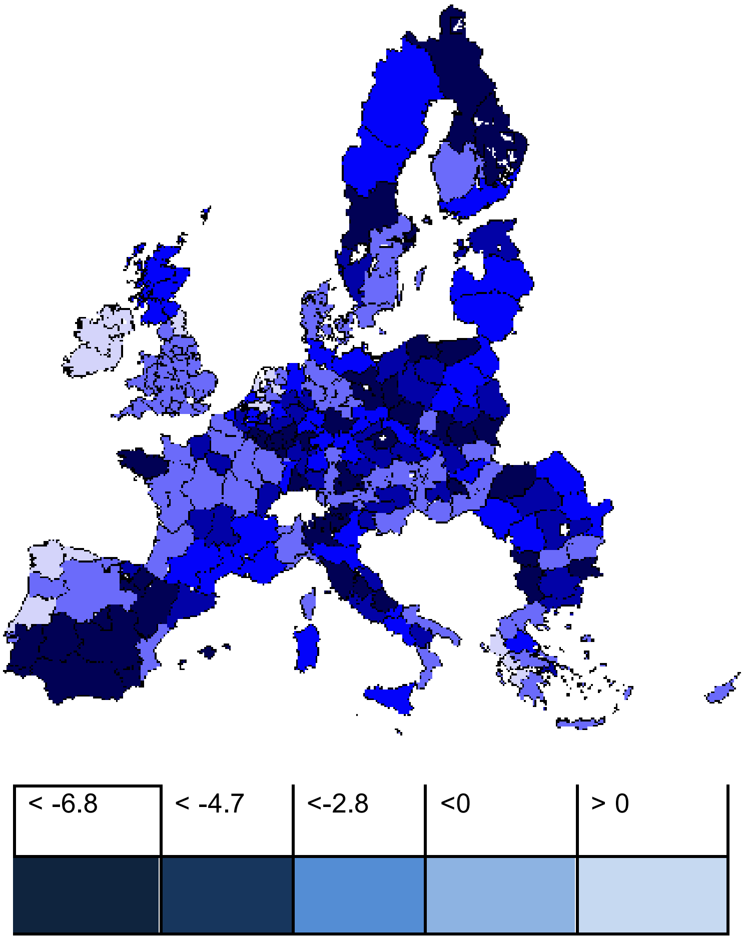
- The decrease in UAA is especially large in regions with relatively low revenue from agricultural production and relatively high GHG emissions.
- The impact on UAA is strengthened by relatively high land supply elasticities, resulting in a significant decrease in the supply of land when the price of land diminishes.
- The decrease in UAA dampens the impact on the land price and this in turn dampens the switch to low-input technologies.
- It should be noted that in this partial-equilibrium analysis CO_2 emissions outside agriculture are not included. This means that we overestimate the decrease in UAA and also underestimate the switch to low-emission technologies.



Map 28. Change in UAA per NUTS2 region in CarbonB2 scenario (percentage difference compared to reference)

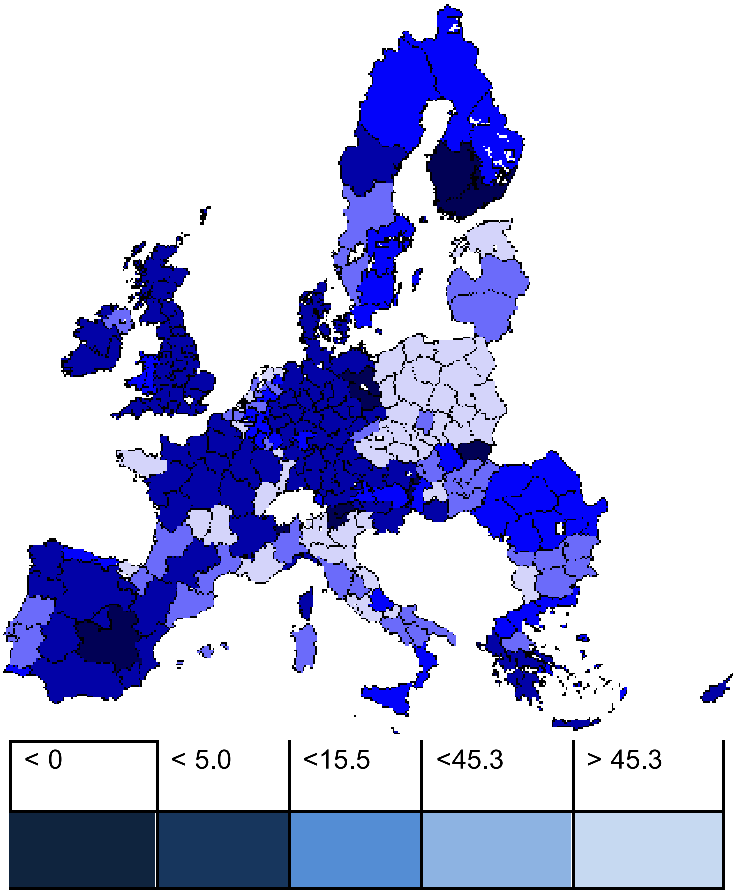
Next we review the effect by region on major crops and livestock categories. Map 29 does this for cereals.

- In Friesland (Netherlands) the acreage of cereals increases. This is explained by the large share of grassland in the regional cropping plan. The acreage of grassland decreases, due to the extra costs of grassland as a consequence of the carbon tax. This in turn decreases the land price. That decrease offsets the carbon tax payments connected to cereals production.
- In Scotland the acreage of cereals decreases. As in Friesland the land price will decrease. However, in this case this is not enough to offset the carbon-tax payments. The relatively large decrease in UAA in Scotland also contributes to this.



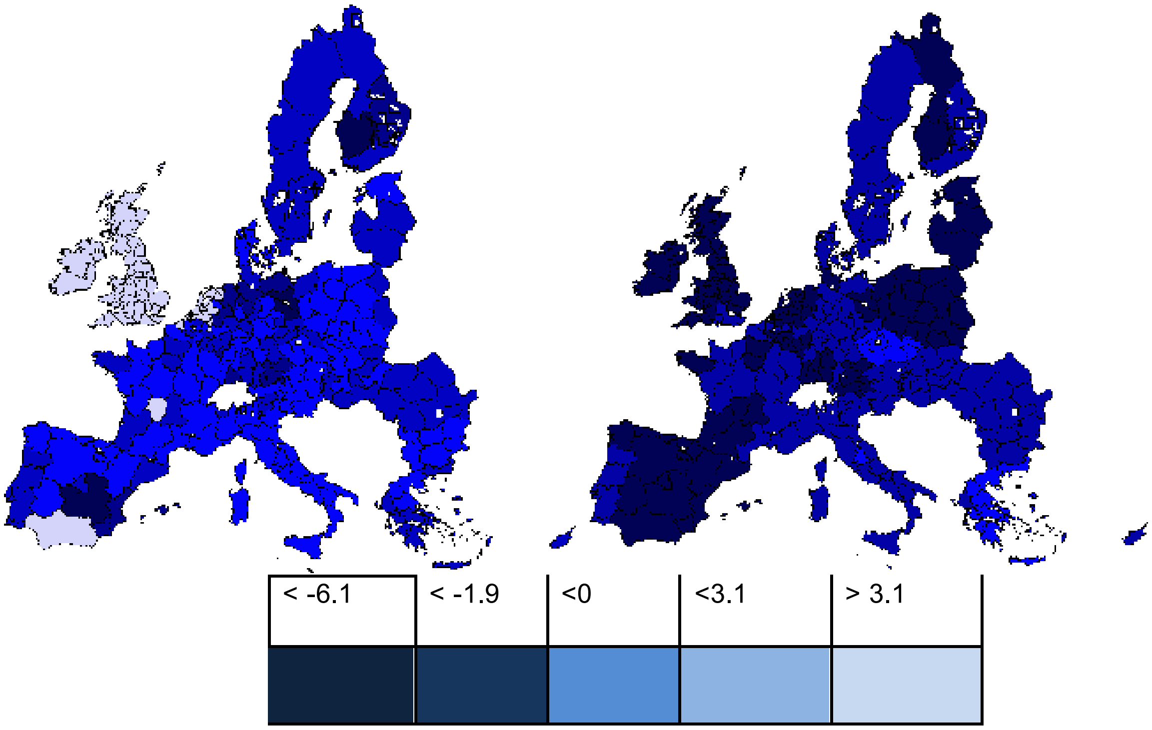
Map 29. Change in cereals area per NUTS2 region in CarbonB2 scenario (percentage difference compared to reference)

Increasing fallow land is also a way to avoid the carbon tax. Hence fallow increases throughout the EU-27, although at different rates per region (Map 30). Given the CAPRI methodology, in absolute figures this is especially important in regions with high levels of set-aside and fallow land in the reference scenario. In percentage terms, the increase in fallow is highest in Poland, the Baltic states, and regions in the Netherlands, Belgium, France, and Italy. As the initial share of fallow in these areas is relatively low, not much tax is avoided.



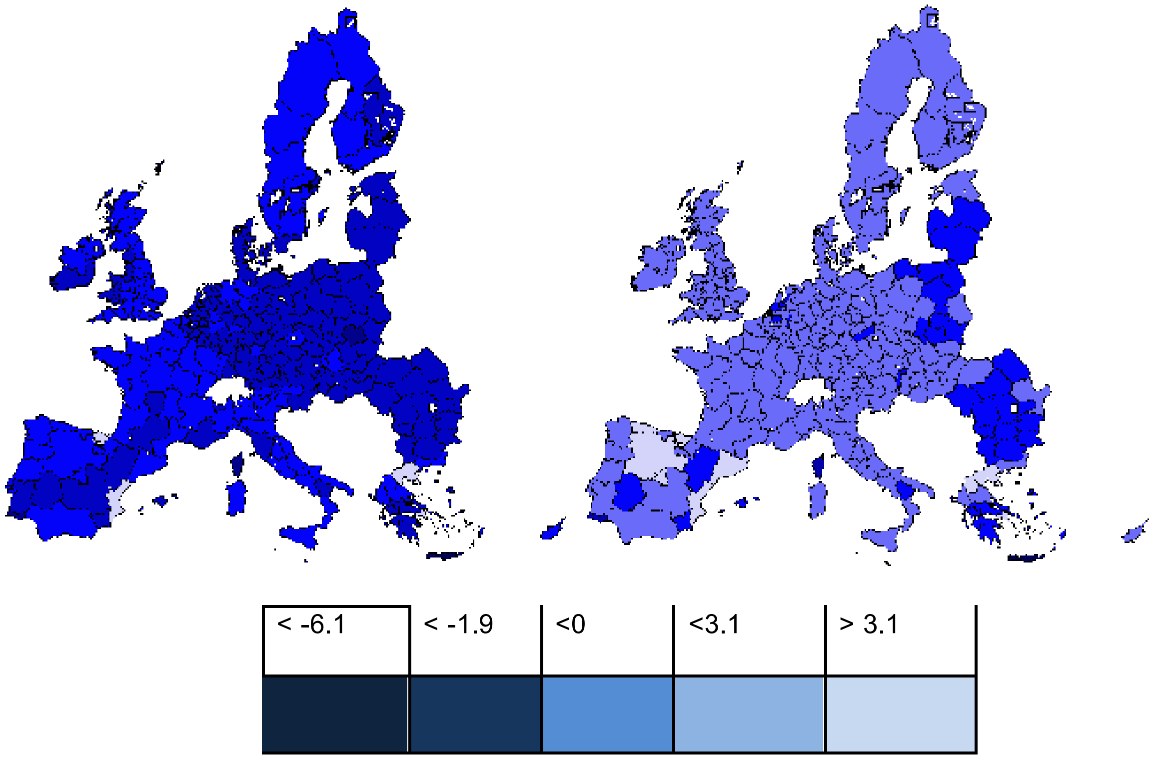
Map 30. Change in set-aside and fallow land acreage per NUTS2 region in CarbonB2 scenario (percentage difference compared to reference)

The relative switch from intensive to extensive grassland is depicted on Map 31. This switch can be explained by lower land prices, which, for extensive grassland, offsets the increase in costs due to the carbon tax. As we saw in Table 20, on intensive grassland the negative impact of the carbon tax on revenue is much higher.



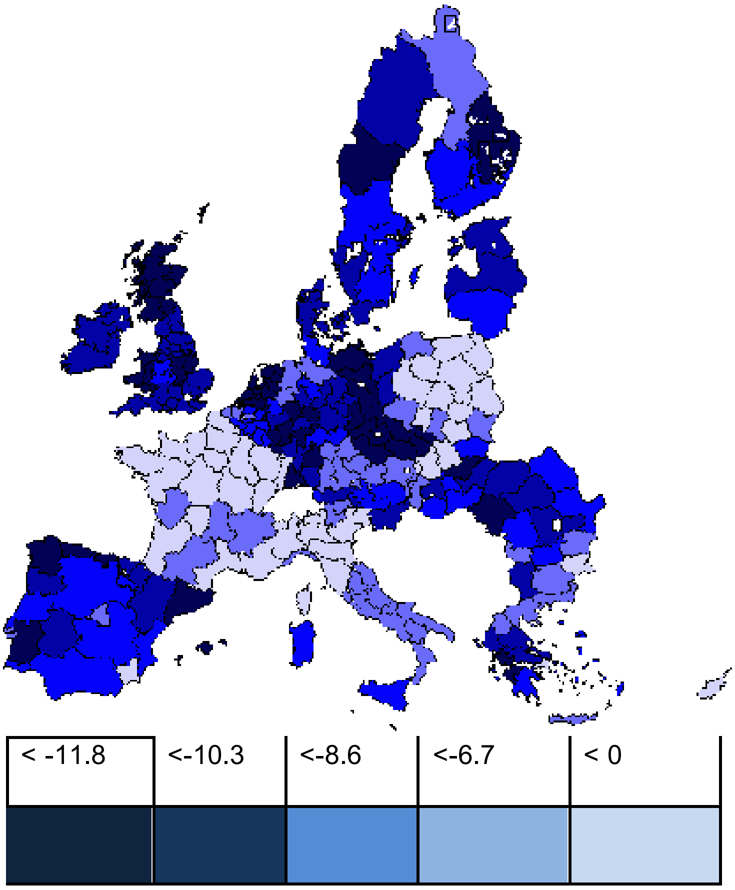
Map 31. Change in acreage of extensive grassland (left panel) and intensive grassland (right panel) per NUTS2 region in CarbonB2 scenario (percentage difference compared to reference)

High-yielding dairy cows are more efficient than low-yield ones: they produce less GHG emissions per kg of milk. This explains why the carbon tax they pay, although higher in absolute terms than the tax paid for low-yield cows, is lower as a percentage of their output. Hence the tax will cause a shift from the former to the latter (Map 32).



Map 32. Change in dairy cows low yield (left panel) and dairy cows high yield (right panel) per NUTS2 region in CarbonB2 scenario (percentage difference compared to reference)

The effect on beef farming is more regionally varied than on the type of dairy, as Map 33 shows. The carbon tax weighs relatively heavy on this sector (Table 20), and moreover, as argued in subsection 5.7.1, the price of feed increases.



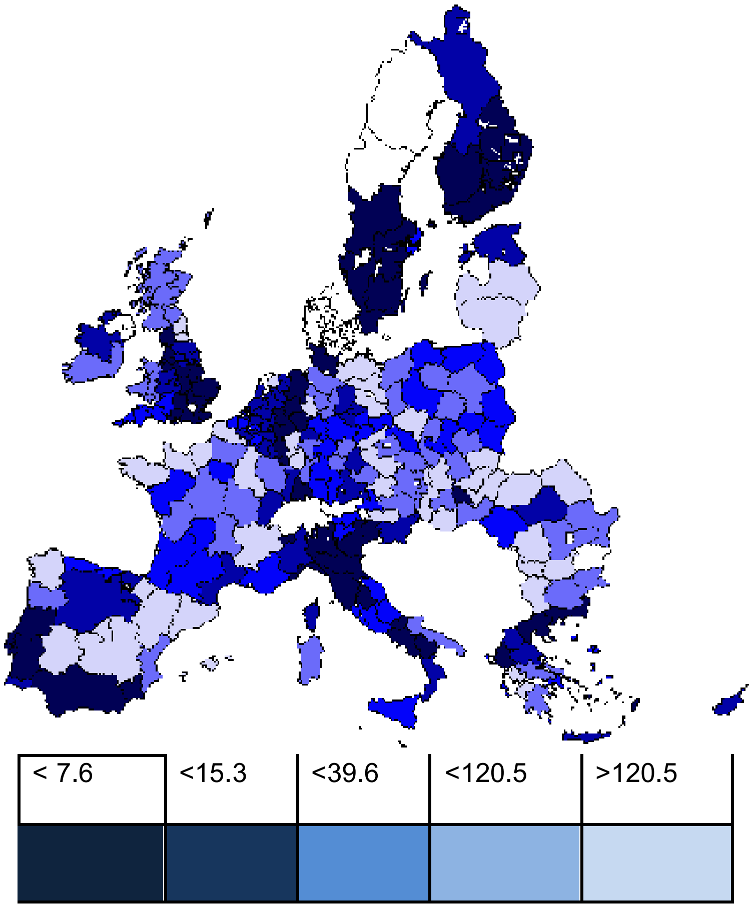
Map 33. Change in beef meat activities per NUTS2 region in CarbonB2 scenario (percentage difference compared to reference)

For the intensive livestock industry, the differential effect of the carbon B1 scenario (i.e. with a CO2 price of 7€ per tonne as in B1, but now with a compensatory subsidy per hour of labour) is shown in Table 22. We see a decrease in all livestock types, but much more in pig-farming than in the poultry sector. In Bulgaria and Romania, however, the impact on pig-farming is very slight, whereas Spain (the largest pork producer in the EU) is relatively heavily affected. In the pooultry sector it is the Czech Republic and the Netherlands which suffer the largest decreases.

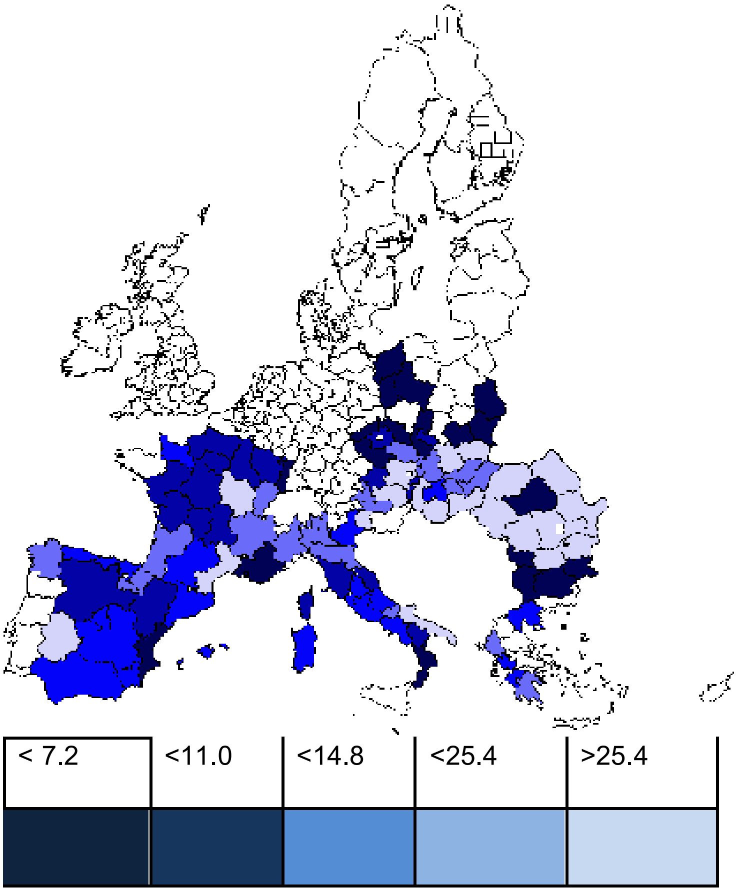
Table 22. Impact of Carbon B1 scenario on intensive livestock industry per member state (Reference scenario: number of heads; pig fattening and pig breeding: *1000; Laying hens and poultry fattening: *100.000)

	Reference				**Carbon B1**			
	Pig fattening	Pig Breeding	Laying hens	Poultry fattening	Pig fattening	Pig Breeding	Laying hens	Poultry fattening
EU-27	258,286	14,522	470	6,446	-2.1%	-2.2%	-0.4%	-0.8%
EU-15	223,729	11,906	338	5,059	-2.1%	-2.2%	-0.4%	-0.7%
12 new member states	34,556	2,615	132	1,387	-2.1%	-2.1%	-0.4%	-1.0%
Belgium	11,170	548	9	197	-2.6%	-2.1%	-0.9%	-1.0%
Denmark	27,220	1,366	4	138	-1.8%	-2.3%	0.0%	-2.4%
Germany	50,433	2,453	36	609	-2.4%	-1.6%	-0.3%	-0.7%
Austria	4,922	292	6	60	-1.4%	-1.0%	0.9%	-0.4%
Netherlands	21,202	1,027	42	383	-1.8%	-2.8%	-1.9%	-2.4%
France	25,553	1,200	49	806	-2.3%	-1.2%	-0.1%	0.1%
Portugal	5,725	248	9	223	-1.2%	-1.4%	-0.3%	-0.6%
Spain	46,572	2,954	55	901	-2.6%	-3.6%	-0.2%	-0.6%
Greece	1,274	107	11	122	0.0%	-2.2%	-0.9%	-1.3%
Italy	13,434	800	51	517	-1.7%	-1.7%	0.4%	-0.3%
Ireland	3,378	163	5	59	-1.0%	-0.7%	-0.4%	-0.8%
Finland	1,945	141	3	53	-1.0%	-2.4%	-0.3%	-0.8%
Sweden	2,405	135	5	87	-1.8%	-2.0%	0.2%	-1.7%
UK	8,496	472	53	906	-1.0%	-1.9%	-0.7%	-0.8%
Czech Republic	3,000	195	10	141	-2.2%	-2.7%	-2.2%	-2.1%
Estonia	592	36	1	10	-1.3%	-1.1%	0.0%	0.0%
Hungary	3,018	261	11	148	-2.1%	-2.4%	-0.2%	-0.7%
Lithuania	1,164	84	4	44	-0.3%	-1.2%	-0.6%	-0.8%
Latvia	560	58	2	12	-2.4%	-3.9%	-0.8%	-1.3%
Poland	20,301	1,468	51	711	-2.5%	-2.2%	-0.4%	-1.1%
Slovenia	271	34	1	31	-0.5%	-2.6%	1.3%	0.1%
Slovakia	322	23	6	57	-0.3%	-0.3%	-0.8%	-0.5%
Cyprus	757	53	0	13	-4.1%	-7.4%	0.0%	-0.1%
Malta	80	7	0	2	-1.5%	-5.2%	0.0%	-0.5%
Bulgaria	473	41	7	53	0.1%	-0.2%	-0.3%	-0.5%
Romania	4,019	354	39	164	-0.5%	-0.5%	0.2%	-0.5%

As is to be expected, legumes benefit greatly from the carbon tax, as shown in Maps 34 (for pulses) and 35 (for soybean). However, due to the way CAPRI is structured, it can only simulate increases in those regions where the crop is already grown, not its expansion to new areas. In other words, the true impact onof a carbon tax on growing legumes could be considerably higher than estimated here.



Map 34. Change in area under pulses per NUTS2 region in CarbonB2 scenario (percentage difference compared to reference). White means that no pulses are grown in the region in the reference scenario



Map 35. Change in area under soybean per NUTS2 region in CarbonB2 scenario (percentage difference compared to reference). White means that no pulses are grown in the region in the reference scenario

5.7.4 Environmental impact

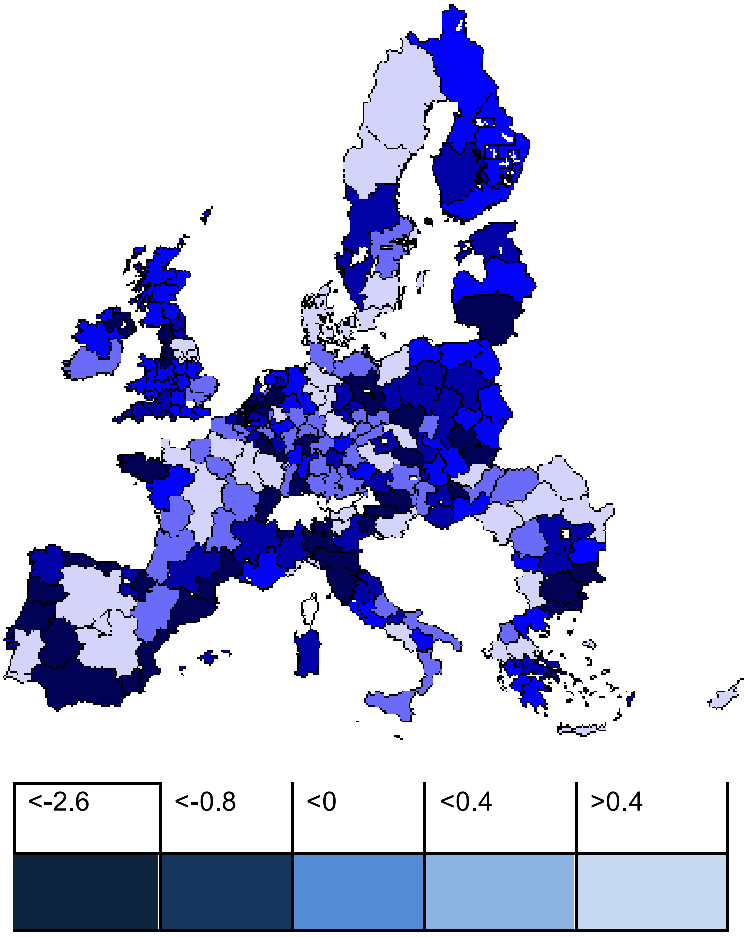
As Table 23 shows, the several variants of a carbon tax policy all lead to a lower nitrate surplus, but mostly so under the B2 variant. This is not only due to planting more legumes, but also to land being taken out of production (decrease of UAA and conversion to set-aside/fallow) or being used less intensively (the case of grassland).

Table 23. EU27 average nitrate budget in 2020 reference scenario and under different alternative scenarios (1000 tonnes N).

	Reference	CarbonA1	CarbonA2	CarbonB1	CarbonB2
Input with mineral fertilizers	10,690	-0.8%	-1.1%	-3.3%	-4.4%
Input with manure (excretion)	9,086	-0.2%	-0.9%	-0.7%	-3.6%
Input with crop residues	9,579	-0.7%	-1.0%	-2.5%	-3.8%
Biological nitrogen fixation	1,549	1.2%	0.8%	5.4%	3.8%
Atmospheric nitrogen deposition	2,194	-0.1%	-0.4%	-0.2%	-1.6%
Nutrient export with crop products	21,528	-0.4%	-0.8%	-1.6%	-3.2%
Surplus total	11,570	-0.6%	-1.0%	-2.1%	-4.0%

The nitrate input per arable activity per hectare changes very little, but mineral fertiliser is replaced by animal manure, crop residues and biological nitrogen fixation. This relatively limited impact on nitrate input per ha is explained by the continued pressure on land markets through the decrease of agricultural land supply.

As stated above, the impact on nitrate from mineral fertiliser exceeds the impact on total nitrate input per ha. The regional impact on nitrogen from mineral fertiliser per ha cereals is presented in Map 36. The change in mineral fertiliser per ha for cereals ranges from more than -10% in Brandenburg (Germany), Murcia (Spain), Lombardia (Italy), Asturias (Spain) and Overijssel (Netherlands), to more than +2% in Liguria and Trentino-Alto Adige (Italy); Nord-Est (Romania); Crete and the Ionian Islands (Greece); Limousin (France); Algarve, Alentejo and the Azores (Portugal); Middle and Upper Norrland and Småland (Sweden); and Slovenia.



Map 36. Change in nitrate from mineral fertiliser per ha per NUTS2 region in CarbonB2 scenario (percentage difference compared to reference)

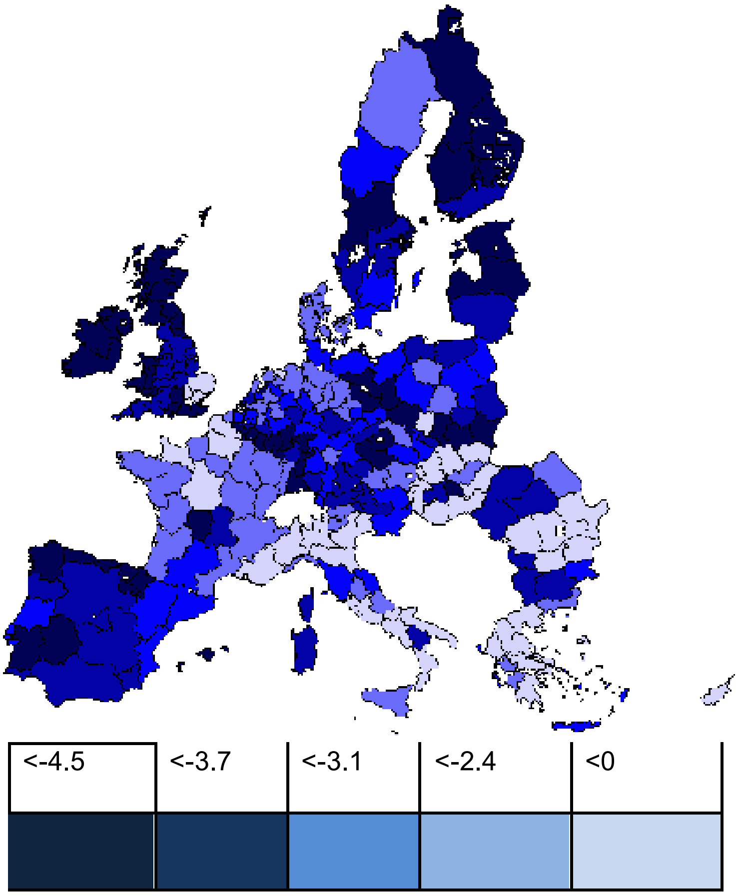
Last but not least, we must consider the impact of the carbon tax on greenhouse gas emissions (Table 24). As Map 37 shows, global warming potential decreases everywhere, but not everywhere to the same extent: the strongest decrease can be seen in Ireland, Finland, Scotland and the Baltic states.

Table 24. Impact of carbon tax on global warming potential

	Reference			Carbon B2		
	Total (1000 tonnes)	*Impact on GWP (1000 tonnes CO_{2e})*		*Total*	*Impact on GWP*	
NH_3 output	2,412			2,332		
Change				-3.3 %		
CH_4 total emissions	7,899	165,879		7,617	159,957	
Change				-3.6%	-3.6%	
N_2O Total emissions	743	230,330		716	221,960	
Change				-3.4%	-3.4%	
Global warming potential (GWPT)	396,156			381,954		
Change				-3.6%		

Notes: 1. For this simulation, an updated version of CAPRI has been used, which means that the figures for the reference scenario differ slightly from those used in the other policy scenarios.

2. The calculations in CAPRI do not include the CO2 emissions from fertiliser production, nor the additional carbon storage under legume cultivaton. The actual effect of the policy scenario is therefore larger than shown in this table. These effects are dealt with in Deliverable 4.6.



Map 37. Change in Global Warming potential per NUTS2 region in CarbonB2 scenario (percentage difference compared to reference)

6. DISCUSSION AND CONCLUSIONS

The expectation for the reference scenario is that the total area under grain legumes will decline further, as it has done for several decades. This decline will be smaller than the expected decline in arable land, so the proportion of legumes in arable land will actually increase slightly.

Except for the carbon tax options, the policy scenarios we examined have only a small effect on the area of grain legumes in the medium term. A carbon tax would be highly effective, even when the variant with the lowest impact (low CO_2 price and no labour subsidy) would be used. The autonomous scenario of increased use of GM varieties of soya would also lead to a large increase in area, large enough to compensate for the decreases in recent years (Figure 3). For forage legumes, the figures are insufficiently complete. However, their cultivation on arable land increased by 33% in the period 2000-2010 in those 16 EU countries for which figures in both years are available; changes in the percentage of clover in grassland (with which our scenario is concerned) are not known.

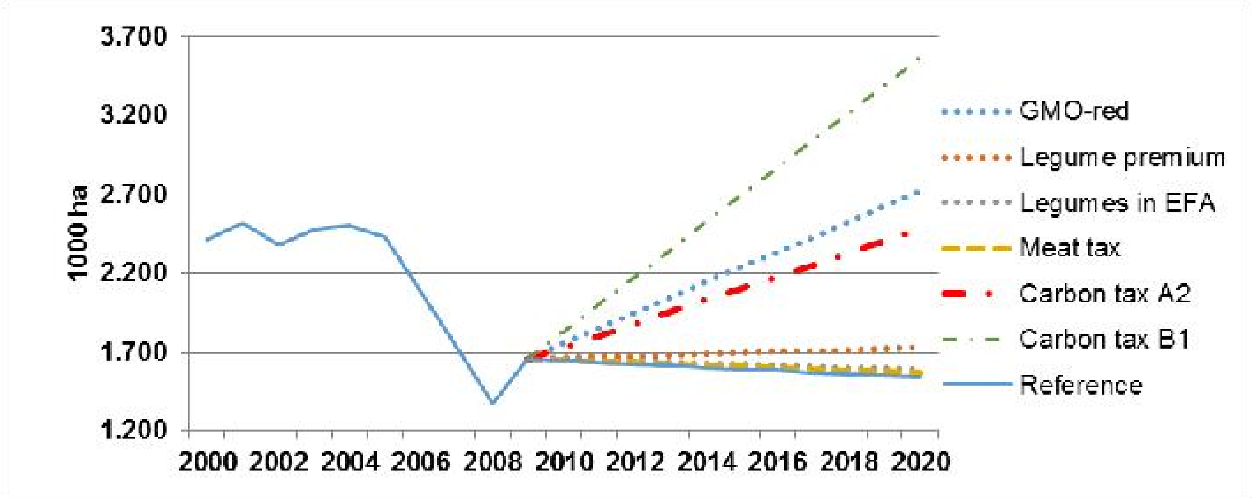


Figure 3. Area cultivated with grain legumes under different scenarios

This difference between autonomous development and deliberate policies does not mean that the impact of policies is necessarily limited. Quite the contrary: the history of legume cultivation over the last 50 years (cf. Figure 1, Chapter 2) shows that arable farmers strongly respond to incentives and disincentives regarding legumes. However, the instruments currently available in the CAP offer only limited scope for steering arable farming in a desired direction.

There are other possible autonomous developments which may influence the area under legumes, which we have not been able to model in the present exercise. One of these is the global food situation. With increasing prosperity and (albeit more slowly) growing population, the global demand for animal products has increased rapidly in recent decades and may be expected to rise further. This will lead to rising demand for soy, and therefore rising prices. Europe may then be forced to grow a larger share of the legumes it consumes within Europe itself. This effect may be reinforced by climate change: although agricultural productivity in parts of southern Europe may decline, in the north it is likely to increase. At the same time, in some parts of the world where the demand for livestock products will rise the most (particularly in Asia), climate change is expected to have a negative impact on agricultural potential. What happens to legumes in such a situation may be comparable to the GMO scenario modelled here.

Another possibility is a continued rise in the price of fertiliser, especially nitrogen-based compounds. The nitrogen component of inorganic fertilisers is most often in the form of ammonium nitrate or of urea, both of which use ammonia as a feedstock. This ammonia is commonly produced from natural gas and the nitrogen in the air, with gas making up the bulk of the production cost. Alternative methods are also highly energy-intensive. Hence, the price of nitrogen fertiliser strongly depends on energy prices. The cost of nitrogen fertilisers rose by over 220% in the period 2000-2011,[71] which means an increase in real terms of 170%. Relative to agricultural producer prices the increase is less spectacular, but still substantial: 63% for wheat and 78% for milk.[72]

Consumption of both natural gas and energy in general will undoubtedly increase significantly in the decades to come: the EIA expects an increase in the consumption of natural gas of 56% between 2013 and 2039.[73] Whether the price will increase proportionally is difficult to say, as this depends partly on the current expansion of shale gas production and partly on the scarcity of other energy sources.

Clearly, developments in GM soya could potentially lead to a very large disruption in the supply of animal feed, and therewith to a large increase in legume crops in Europe. However, if the policies of the EU and its member states towards genetic modification would become more tolerant (for instance by establishing thresholds for the low-level presence of non-certified varieties in shipments, or by accepting GM varieties approved by exporting countries), then such a scenario will not come to pass. Still, the scenario shows what may happen as a result of autonomous developments.

Turning to policy scenarios, we have three instruments for promoting grain legumes on arable land and one for forage legumes either on arable land or intersown with grass. Starting with the policies for grain legumes, the hectare premium (such as existed until recently in the CAP for peas, field beans and sweet lupins) appears to be the most

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[71] Bues op. cit., 28, based on figures from Eurostat.

[72] Ibid.; the price used is the value ratio of 1kg of urea to 1 kg of wheat or milk.

[73] U.S. Energy Information Administration, 2013. International Energy Outlook 2013. http://www.eia.gov/forecasts/ieo/more_highlights.cfm

effective in increasing the area under grain legumes – although even so it cannot reverse the decline that has taken place in recent years. It leads to a small increase in farmers' incomes (although achieved by arable farmers at the expense of livestock farms). There are positive environmental effects compared to the reference scenario, but because the effect on land use is small the same is true for any impact of land-use change.

This is even more true for the other two grain-legume policies: allowing legumes to qualify for Ecological Focus Areas and providing incentives for consuming more pulses and less meat. However, the EFA policy produces significant results in some countries, which could be a reason for letting member states decide on how to implement EFAs. The subsidy for grain legumes for food produces environmental benefits beyond the mere effect on legume cultivation, because of the concomitant reduction in meat consumption. However, this limited advantage may be undone by more intensive and large-scale farming – pushed by the squeeze on margins in animal production. Average farm incomes decline under this scenario.

Modelling a policy for forage legumes is difficult in CAPRI, because they are not included in the model as distinct crops. The tests reported here were done with clover in grassland, so a policy to increase that proportion was designed. By definition, this will lead to a significant increase in legumes. It will increase the production cost for livestock farmers, but against that stand environmental benefits, most notably a lower need for nitrogen fertiliser and a lower nitrogen surplus. In Deliverable 4.6 it will be attempted to weigh these benefits and costs against one another.