# Genetically modified soy, an irreplaceable raw material in the EU.

# Assessment of alternatives and economic impact on the Spanish fodder industry and livestock farming sector

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**Summary**

This study analyses the importance of genetically modified (GM) soy as a raw material that cannot be replaced in the fodder industry, facing the EU's restrictions on GM soy imports. This study assesses a series of alternatives and measures the impact of these alternatives on the price of soy and on the fodder industry and different livestock industries in Spain. To do so, national and international sources of statistical information have been used, in relation to the production, price and international trade of conventional and GM soy during the 2000-2014 period (Datacomex, FAOstat, USDA), as well as information derived from enquiries made to Spanish livestock farming associations.

The study shows the importance of GM soy for the fodder production industry and livestock farming industry, given its high protein content and the competitive price of the protein. This study describes the international trade of soy, focusing on soy imports by Europe and Spain.

The information provided by national and international organisations has been used to estimate that the Spanish GM soy imports during the 2000-2014 period have led to savings of at least €55,000M, as opposed to the alternative of solely importing conventional soy during this period. This has been due to the high cost of importing conventional soy and its relatively high price.

This study analyses the feasibility of the two alternatives to importing genetically modified (GM) soy in Spain. The first would involve the exclusive importation of conventional soy, while the second would involve the increase in the national production of alternative crops that provide the necessary protein content.

As regards the first alternative, it is concluded that there would be a shortage in the supply of this raw material to the fodder production industry in the *short-term*. As a consequence, this industry would have to seek for alternative sources of protein in other oilseeds. However, it is improbable, at least in the short-term, that the protein content provided by soy could be completely replaced. Previous studies have indicated that there are no intentions to develop large-scale domestic production systems with protein-rich plants, estimating that only 10 to 20% of European soybean and soybean meal imports could be replaced. Therefore, most of the supply would have to be secured from sources abroad. This would lead to a reduction in the European livestock farming product production and the need to import these products from abroad.

As regards the second alternative, the possibility of replacing the protein from soy with an increase in the production of other crops in Spain, such as broad beans, peas, lupin beans or sunflower, is not feasible, due to the vast surface area required to cater to the demand of protein that is required to cover the current demand for GM soy.

In addition to its supply to industry, it would be more expensive due to the 294% increase in the prices of soy in the short-term. Such an increase in prices would have a long-term impact on the production chain of livestock farming products. Therefore, this would lead to a 49%, 54% and 85% increase in the cost of fodder production ingredients for cattle, pigs and poultry, respectively. With the data of the input-output tables, it is estimated that the increase in the price of soy would have an 11.3% impact on the production of fodder, which would result in an impact on the cost of production of eggs, poultry meat, pork and beef of 7.1%, 8.0%, 8.1% and 4.6%, respectively.

Both the increase in the prices of conventional soy and the impossibility to fully replace the proteins provided by GM soy mean that the fodder production industry would be greatly affected and there could be a risk of the dismantling of this industry in the European Union. As a consequence, the European livestock farming industry would also face a shortage in the supply of fodder for livestock feeding, since it would not be able to cover the requirements with fodder imported from third countries, which are mainly produced from genetically modified raw materials.

## 1. Introduction

The European Union greatly depends on the importation of protein-rich products required to manufacture fodder, such as soybeans and soybean meal. These products are needed for the production of products derived from livestock farming, such as meat, milk or eggs. Both the production of raw materials used to manufacture fodder and the livestock farming production play a very important role in the current global context. Such a relevance will increase in the future, taking into account the growth perspectives of the world population and the modification of feeding patterns in emerging countries, which will lead to an increase in the demand for meat and dairy products.

The purpose of this study is to assess the feasibility of the three alternatives to the importation of genetically modified (GM) soy in Spain, as well as the effects of an increase in the demand of alternatives to GM soy on its prices. *Firstly*, the global evolution of GM crops is described, explaining the importance of soybeans in the production of fodder and providing information about cultivation, trade and importation of soybeans and soybean meal. *Secondly*, the economic impact of importing GM soy by Spain during the 2000-2014 period is estimated. *Thirdly*, the feasibility and impact of replacing GM soy imports with conventional soy is analysed. To do so, the global conventional and GM soy production data is used, considering the possibility of having the adequate volumes of conventional soy that can replace GM soy imports. *Fourthly*, this study analyses the possibility of replacing the protein obtained from soy with that of other crops at the Spanish level, such as that of broad beans, peas, lupin beans or sunflower. *Fifthly*, this study analyses the feasibility of importing sunflower seeds and the impact of an increase in demand on the price of sunflower seeds.

In addition, the economic impact of a potential change in the price of fodder ingredients on the production costs of the fodder manufacturing sector is analysed, using the forecasts on the impact on prices of replacing the GM soy imports with conventional soy, including the impact on fodder used to produce eggs and poultry meat, beef and pork. The impact of this on the costs of production of different Spanish livestock farming sub-sectors will also be analysed. These sub-sectors depend on soy, since it is an essential component in the production of fodder. The national and international sources of statistical information have been used as the main sources of information of this study, in relation to the production, price and international trade of conventional and GM soy during the 2000-2014 period (Datacomex, FAOstat, Eurostat, MAGRAMA), as well as information derived from enquiries made to Spanish livestock farming associations.

## 2. Genetically modified (GM) crops

In 2014, a total of 181.5 million hectares were used for cultivating genetically modified crops in 28 countries (James, 2015). The following table shows the total cultivated surface area of GM crops per country.

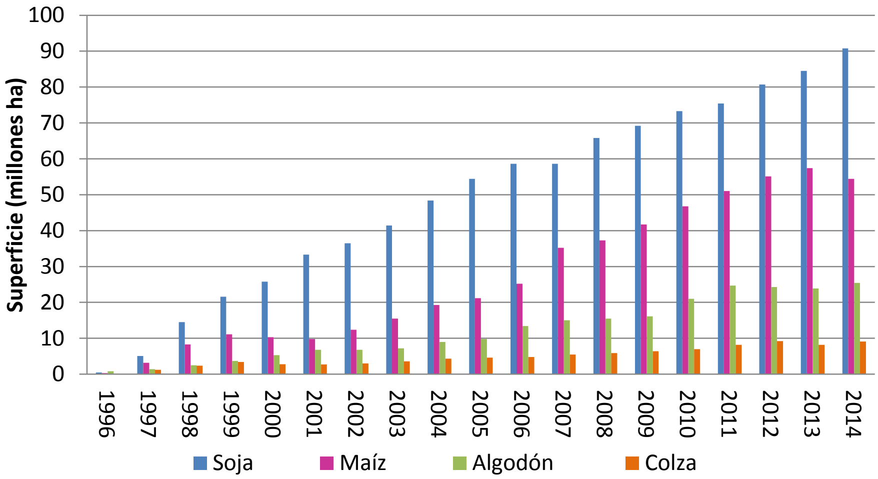
**Table 1- Global distribution of GM crops**

| | Surface area (million hectares) | GM Crops |
|---|---|---|
| **Unites States** | 73.1 | Corn, *soy*, cotton, rapeseed, beet, alfalfa, papaya, courgette |
| **Brazil** | 42.2 | *Soy*, corn, cotton |
| **Argentina** | 24.3 | *Soy*, corn, cotton |
| **India** | 11.6 | Cotton |
| **Canada** | 11.6 | Rapeseed, corn, *soy*, beet |
| **China** | 3.9 | Cotton, papaya, black poplar, tomato, pepper |
| **Paraguay** | 3.9 | *Soy*, corn, cotton |
| **Pakistan** | 2.9 | Cotton |
| **South Africa** | 2.7 | Corn, *soy*, cotton |
| **Uruguay** | 1.6 | *Soy*, corn |
| **Bolivia** | 1.0 | *Soybeans* |

Source: Developed by the author with James' data (2015)

Soy continues to be the GM crop with the highest cultivated surface area worldwide (91 million hectares and an 82% level of adoption), followed by corn (55 million hectares and a 30% level of adoption), cotton (25 million hectares and an 68% level of adoption), rapeseed (9 million hectares and an 25% level of adoption) and other crops with a smaller presence, such as beet, alfalfa, papaya, etc. (approximately 1 million hectares). The surface used for GM crops has increased constantly during the last 18 years, Figure 1 (James, 2012).

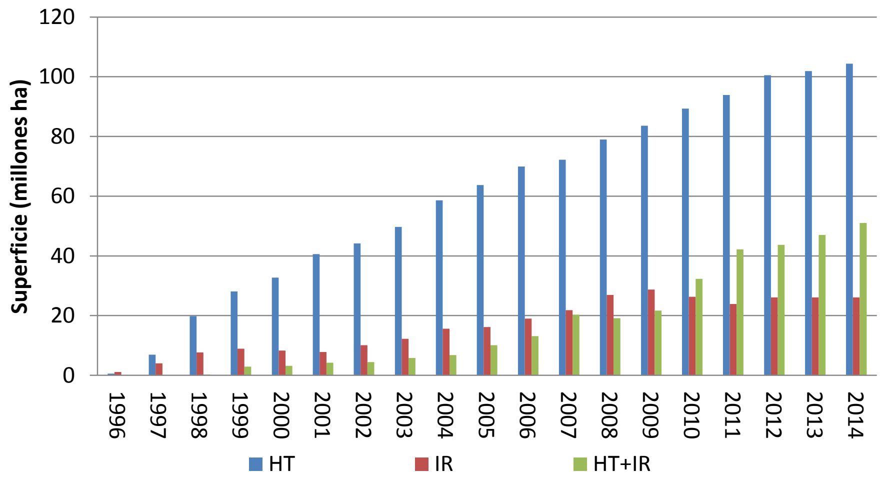
**Figure 1. Evolution of the main GM crops (1996-2014)**




Source: Developed by the author with James' data (1998-2015)

As regards the genetically modified crops being currently marketed, two characteristics can be highlighted: crops tolerant to determined herbicides (herbicide-tolerant, HT) and crops resistant to determined plagues (insect-resistant, IR). HT crops have been in the highest demand by farmers since they started being marketed, holding 59% of the surface destined to genetically modified crops in 2015 (93.9 million hectares), while IR crops only represent 13% of the total (23.9 million hectares). The crops that combine both technologies (HT+IR) have experienced a rapid growth, representing 28% of the total amount of genetically modified crops (51 million hectares) and new crops marketed, such as crops resistant to drought, which were adopted for the first time in the United States in 2013 (James, 2014).

**Figure 2. Evolution of the main GM crops (1996-2014)**




Source: Developed by the author with James' data (2015)

The growing adoption of GM crops can be explained by the advantages of these crops in relation to conventional crops (Riesgo and Areal, 2014).

On the one hand, the profitability associated with GM crops is higher than that of conventional varieties, as a result of a combination of higher yields and lower costs of production. This is particularly true in the case of the IR technology, since numerous studies have shown proof of its higher yield when compared to conventional crops, mainly due to their resistance to determined plagues (Carpenter, 2010; Demont and Tollens, 2004; Gianessi et al., 2002; Gómez-Barbero et al., 2008; Riesgo et al., 2012). Likewise, the adoption of IR crops generates a series of environmental benefits, such as those derived from the reduction in the number of insecticide treatments required, a smaller water footprint as a result of the higher yield of IR crops (i.e., higher agricultural yield requires a smaller surface area to achieve a determined production level and also less water per tonne produced when crops need to be irrigated), as well as a higher net fixation of carbon when compared to conventional varieties (Riesgo, 2013). However, despite the fact that the adoption of the HT technology does not entail a high increase in yield, its use allows farmers to be more efficient in the control of weeds[1] and, therefore, reduce the cost of using herbicides, machine hours and fuel (Bernard et al., 2004; Bullock and Nitsi, 2001; Ervin et al., 2010; Fernandez-Cornejo et al., 2002; Phillips, 2003; Qaim, 2009).

[1] Wide-spectrum herbicides, such as glyphosate or glufosinate, are characterised by eliminating almost all plants, except for those that tolerate herbicides (HT crops), since the latter incorporate genes that are not affected by glyphosate or glufosinate. The use of HT crops simplifies the weed control operations with the simplified use of herbicides and with a more flexible application period in the case of specific herbicides applied to conventional crops (Madsen and Streibig, 2004).

There are a series of benefits derived from the adoption of genetically modified crops, such as the reduction of the use of insecticides, the replacement of selective herbicides by wide-spectrum herbicides, savings in fuel associated with lower treatment volumes, the possibility of using minimum labour or direct sowing techniques associated with the HT technology or the 'halo' effect caused by the IR technology[2] (Devos et al., 2008; Dewar et al., 2003; Ervin et al., 2000; Frisvold and Reeves, 2008; Nelson and Bullock, 2003; Qaim, 2009; Sydorovych and Marra, 2007; Tabashnik, 2010; Wan et al., 2012; Wolfenbarger and Phifer, 2000). The HT technology allows farmers to reduce the time they take to inspect and treat their farms against the problems of weeds (Bullock and Nitsi, 2001; Carpenter and Gianessi, 1999; Ervin et al., 2010; Marra and Piggott, 2006). A positive environmental effect of HT crops is related to the adoption of minimum labour or direct sowing techniques[3]. These techniques are associated with determined benefits, such as the reduction of the risk of soil erosion, increase in the level of organic matter in soils, reduction of runoff water or reduction of the percolation of phytosanitary substances, among others (Carpenter, 2011).

## 3. Soy

Soy is an oilseed that is cultivated to obtain seeds or beans, which can be milled to produce meal and oil. Soybean meal is used as a source of protein for animal feeding. Soybean meal is characterised by: (a) a high protein content (44% of digest protein) and a low content of cellulose (6%), (b) its amino acid composition is balanced and rich in lysine, (c) low anti-nutritional factor levels, (d) high palatability and low fibre content, and (e) relatively low price in relation to its protein content (MAGRAMA, 2014; Jones et al., 2014). These singular characteristics make soy a vital product in the preparation of compound fodder. In relation to extracted oil, it is important to highlight its use in both feeding and industrial uses.

[2] The 'halo' effect refers to a reduction of the damage caused by plagues in conventional crops in areas where IR crops are cultivated.

[3] In conventional agriculture, weeds are controlled with labour-intensive techniques (conventional labour techniques) and by applying wide-spectrum herbicides during the pre-sowing period. This prevents crops from being damaged by weeds during their germination. Subsequently, weeds are controlled using selective herbicides during the plant growth period. In the case of HT crops, weeds can be controlled with wide-spectrum herbicides, not only during the pre-sowing period but also during any period of the crop growth phase, thus facilitating the application of less labour-intensive techniques.

### 3.1. Soybean

#### *3.1.1. Global cultivation of soybeans*

There are currently 94 countries that cultivate soy in the world, although its production is mainly concentrated in three countries: United States, Brazil and Argentina concentrate 80% of the average world production of soy (Figure 3 and Table 2). If China and India are included, these five countries concentrate 90% of the global production of soy. Table 2 shows the main countries producing soybeans and their exports and the degree of adoption of GM soy.

**Figure 3. Global distribution of the soybean production in 2014**


Source: USDA data (map prepared by www.indexmundi.com)

During 2014, a total of 90.7 million hectares of GM soy were registered versus the 22.7 million hectares of conventional soy (James, 2015; USDA, 2015). This surface shows that the level of adoption of this crop reached 80% in 2014 worldwide, as shown in Table 2. In particular, this surface area and the production of GM soybean would concentrate in 8 countries: United States, Brazil, Argentina, Canada, Uruguay, Bolivia and South Africa, by order of importance.

**Table 2. Surface area cultivated, production, exports of soy and level of adoption in GM soy producing countries (2014)**

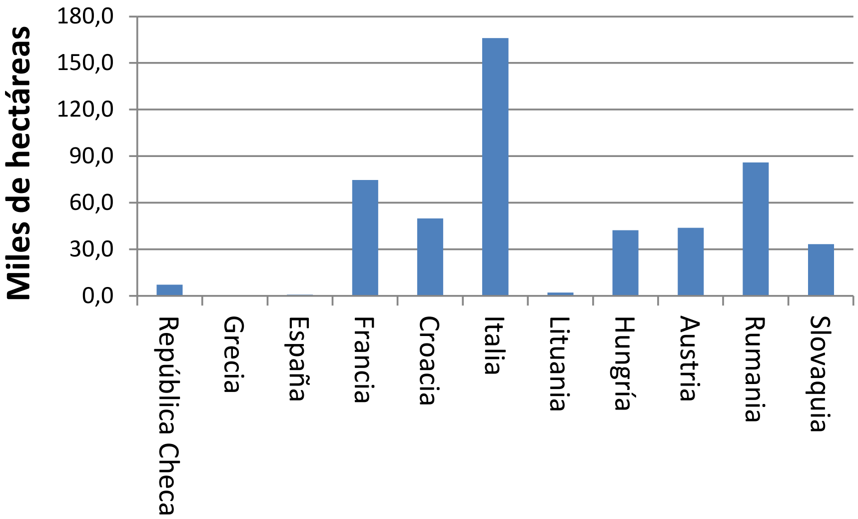
| | Surface area cultivated with soy (million hectares) | Adoption of GM soy (%, 2013) | Total soybean production (million t) | Soybean exports (million t) | Date when GM soy started to be cultivated |
|---|---|---|---|---|---|
| **Unites States** | 30.86 | 93% | 91.39 | 44.82 | 1997 |
| **Argentina** | 19.80 | 100% | 54.00 | 7.84 | 1997 |
| **Brazil** | 30.10 | 92% | 86.70 | 46.83 | 1999 |
| **Paraguay** | 3.20 | 95% | 8.20 | 4.80 | 2004 |
| **Canada** | 1.86 | 90% | 5.36 | ND | 1997 |
| **Uruguay** | 1.45 | 100% | 3.50 | ND | 2002 |
| **Bolivia** | 1.00 | 91% | 2.40 | ND | 2008 |
| **South Africa** | 0.50 | 90% | 0.94 | ND | 2001 |
| **India** | 12.20 | - | 9.50 | ND | - |
| **China** | 6.85 | - | 12.20 | 0.22 | - |
| **Ukraine** | 1.35 | - | 2.77 | 0.57 | - |
| **Total** | **113.33** | **80.03%** | **283.74** | **113.04** | **1997** |

Source: http://www.gmo-compass.org/, http://faostat3.fao.org/download/Q/QC/E, http://www.usda.gov/oce/commodity/wasde/latest.pdf, http://apps.fas.usda.gov/psdonline/circulars/production.pdf

### *3.1.2. Cultivation and trade of soybeans in the European Union*

The European Union (EU-27) cultivated a total of 506,600 hectares of soy during the year 2014; Italy was the Member State with the largest cultivated surface area (32.76%), followed by Romania (16.97%) and France (14.72%).

**Figure 4. Surface area cultivated with soy in the EU-27 during 2014**

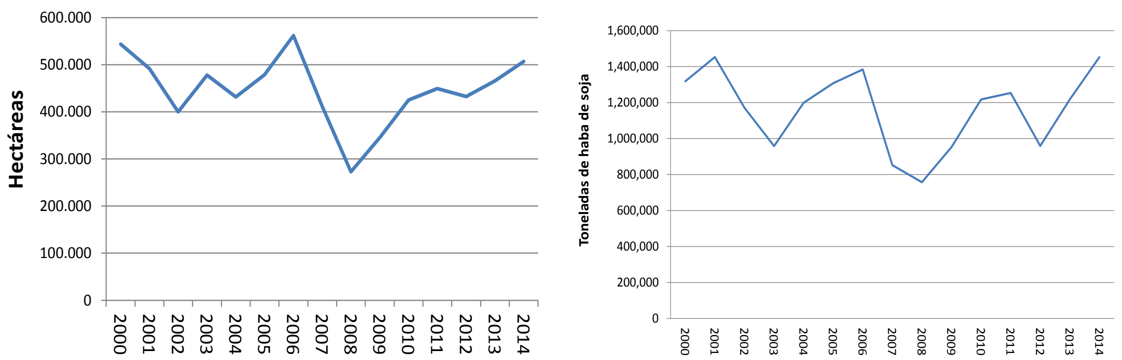



Source: Developed by the author with Eurostat (2014)

Figure 5a shows how this surface area has remained stable during the 2000-2014 period with approximately 500,000 hectares. There was a large reduction in the total surface area cultivated in 2008 (287,600 hectares), mainly due to the reduction in the surface area cultivated with soy in Romania (62.54% drop as compared to 2007). This occurred when Romania became a member of the EU and was forced to stop cultivating HT soy. Such a prohibition led to a large reduction in the surface area cultivated with soy and there was no full replacement with conventional soy.

**Figure 5. Evolution of the surface area and production of soy in the EU-27 (2000-2014)**

| **5a. Soybean surface area (t)** | **5b. Soybean production (t)** |
|---|---|



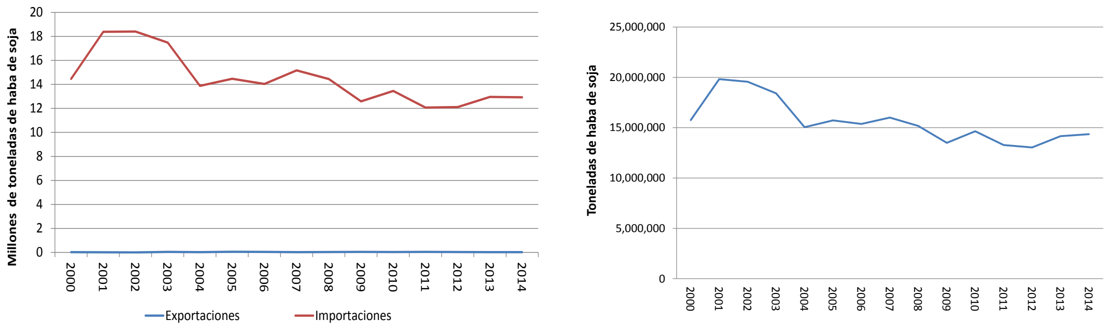

Source: Developed by the author with Datacomex data (2000-2014)

Likewise, such an evolution in the surface area is characterised by the trends in the production of soybeans in the Member States of the EU-27 during the 2000-2014 period (Figure 5b). The larger drop in the production of soy is also due to the reduction in the production suffered in Romania after it stopped cultivating HT soy.

The production of soybeans in the EU-27 is almost fully used to cover internal demand and only around 1% is exported to non-EU countries (in 2014, exports represented 16,786 t, i.e., 1.16% of the production of the EU-27). However, the total internal demand exceeds the production by far, making imports a necessity (see Figures 6a and 6b). Therefore, in 2014, almost 13 million tonnes of soybeans had to be imported.

**Figure 6. Evolution of foreign trade and internal demand of soybeans in the EU-27 (2000-2014).**

| 6a. Soybean exports and imports (t) | 6b. Internal soybean demand (t) |
|---|---|




Source: Developed by the author with Datacomex data (2000-2014)

The average importation volume of soybeans by the European Union during the 2009-2011 period was 14.7 million tonnes, making the EU-27 the second largest importer in the world of soybeans (16%), behind China, which imported a total of 52.4 million tonnes on average during the same period (59%).

**Table 3. Main soybean importers (2009-2011)**

| Country | Quantity (t) | Weight in global importations (%) |
|---|---|---|
| **China** | 52,388,513 | 58.9 |
| **Mexico** | 3,512,820 | 4.0 |
| **Japan** | 3,225,495 | 3.6 |
| **Thailand** | 1,782,545 | 2.0 |
| **Indonesia** | 1,714,580 | 1.9 |
| **Turkey** | 1,342,470 | 1.5 |
| **Republic of Korea** | 1,154,732 | 1.3 |
| **Egypt** | 1,138,926 | 1.3 |
| **Russian Federation** | 972,063 | 1.1 |
| **Iran** | 901,659 | 1.0 |
| **Syria** | 607,759 | 0.7 |
| **Malaysia** | 588,830 | 0.7 |
| ***European Union*** | ***14,665,267*** | ***16.0*** |
| ***World*** | ***88,901,951*** | |

Source: Developed by the author with FAOstat

Germany, the Netherlands and Spain are the main soybean importers of the European Union. These three Member States represent 65% of the total imports of the European Union and 11% of global imports (see Table 4). Soy imported by the Netherlands is mainly redistributed to other countries of the European Union, since the Netherlands provides the point of access to soy for other countries in Europe.

**Table 4. Main soybean importers of the European Union (2009-2011)**

| Country | Soybean imports (thousand tonnes) | Weight in EU importations (%) | Weight in global importations (%) |
|---|---|---|---|
| **Germany** | 3,246 | 22.1 | 3.7 |
| **The Netherlands** | 3,217 | 21.9 | 3.6 |
| **Spain** | 3,079 | 21.0 | 3.5 |
| **Italy** | 1,386 | 9.5 | 1.6 |
| **The United Kingdom** | 845 | 5.8 | 1.0 |
| **Portugal** | 804 | 5.5 | 0.9 |
| **France** | 617 | 4.2 | 0.7 |
| **Belgium** | 604 | 4.1 | 0.7 |
| **Greece** | 283 | 1.9 | 0.3 |
| **Slovenia** | 207 | 1.4 | 0.2 |
| **Austria** | 100 | 0.7 | 0.1 |
| **Denmark** | 93 | 0.6 | 0.1 |
| **Czech Republic** | 26 | 0.2 | 0.0 |
| **Romania** | 24 | 0.2 | 0.0 |
| **Ireland** | 21 | 0.1 | 0.0 |
| **Latvia** | 21 | 0.1 | 0.0 |
| **Sweden** | 19 | 0.1 | 0.0 |
| **Hungary** | 18 | 0.1 | 0.0 |
| **Poland** | 15 | 0.1 | 0.0 |
| ***European Union*** | *14,665* | | *16.5* |
| ***World*** | *88,901* | | |

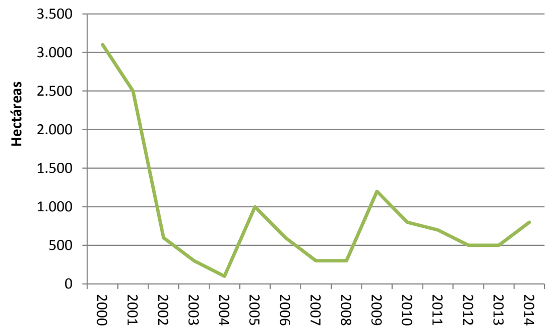
Source: Developed by the author with FAOstat

### *3.1.3. Soybean cultivation and trade in Spain*

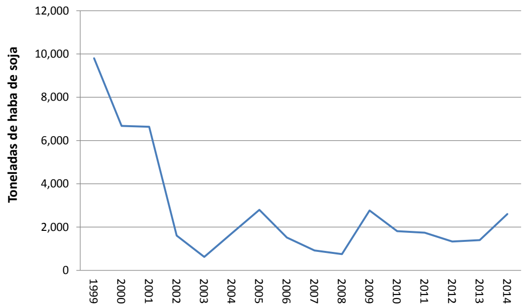
The role of Spain in the cultivation of soy is minor, both in terms of cultivated surface area and production, as shown in Figure 7.

**Figure 7. Evolution of the cultivated surface area and production of soybeans in Spain (1999-2014)**

**7a. Cultivated surface area (hectares)**



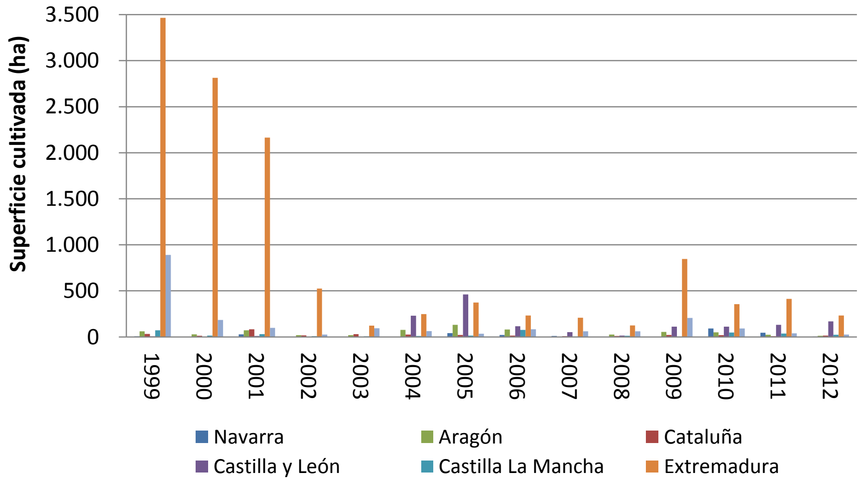

**7b. Production (tonnes)**




Source: Developed by the author with MAGRAMA (2000-2014) and Eurostat (1998-2014)

The above figures show that the surface area and production of soybeans in Spain has dropped since the dawn of the 90s to current times, with a 94% reduction between 1999 and 2003. Therefore, the cultivated surface area dropped from 4,535 hectares in 1999 to 272 hectares in 2003 and to 481 hectares in 2012. Likewise, as regards its production, it also dropped from 9,800 tonnes in 1999 to 2,600 tonnes in 2014. The lower presence of soy in Spain was mainly concentrated in Extremadura (48.23%) and Castilla y León (35.14%) during 2012, as shown in Figure 8.

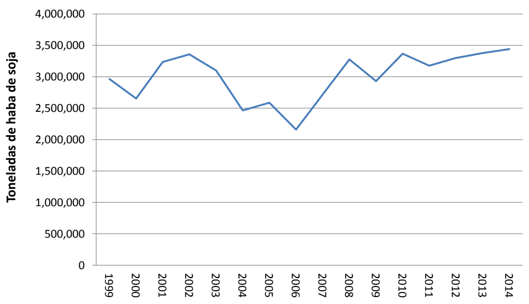
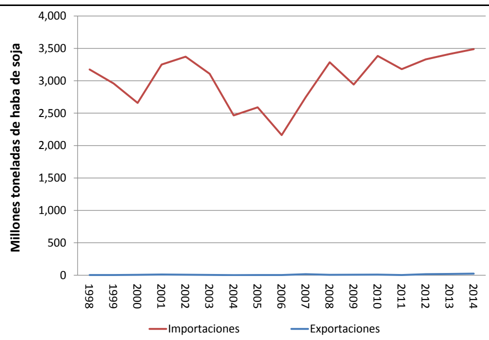
**Figure 8. Distribution of soybean crops in Spain by Autonomous Community (1999-2012)**




Source: MAGRAMA 2000-2014

With such a low internal production, the growing demand for soybeans by the milling and fodder industry has been covered with imports (see Figure 9a). Therefore, Figure 9b shows the evolution of soybean imports since 1998 and until 2014, rising this past year to almost 3 million and a half tonnes. Spain is the fifth largest global soybean importer, behind China, Japan, the Netherlands and Mexico.

**Figure 9. Soybean imports and exports in Spain, excluding Intra-European trade (2000-2014)**

| **9a. Internal demand (t)** | **9b. Foreign trade (million t)** |
|---|---|
|  |  |



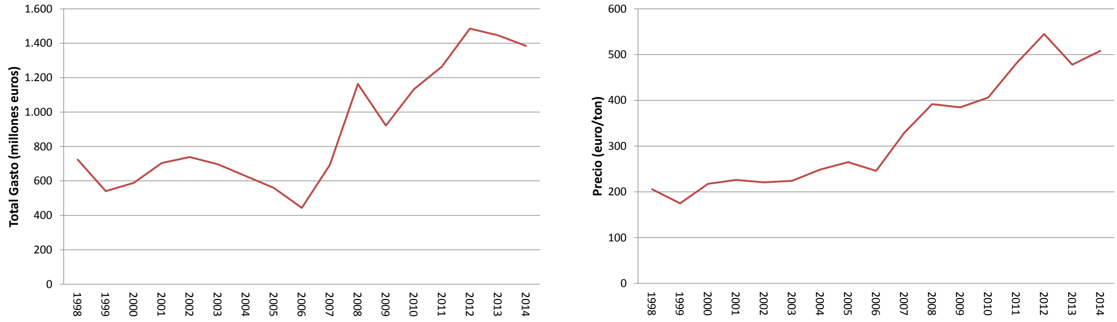


Source: Developed by the author with Datacomex data (1998-2014)

Likewise, taking into account the volume of these imports, Spain imported soybeans for a total of €1,384M during 2014 (see Figure 10a). The volume of soy imports increased after 2006, not only due to the increase in imports of this year but also because of the average increase in prices (see Figure 10b). To this end, the average price of soy imported by Spain has risen, as in the case of most cereals and oilseeds.

**Figure 10. Evolution of the volume of soybean imports in Spain (1998-2014) in current euros**

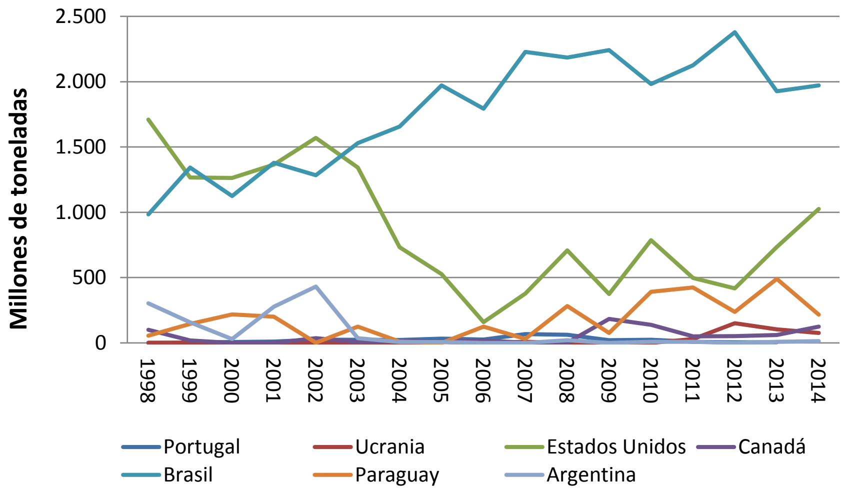
| 10a. Expense (current euros) | 10b. Average price (euros/t) |
|---|---|




Source: Developed by the author with Datacomex data (1998-2014)

Figure 11 shows the main countries that supply soy to Spain, highlighting Brazil (57%) and the United States (29.6%), followed by Paraguay (6.26%), Canada (3.61%) and Ukraine (2.23%). There is a large change in the source of imports since 2002, whereby the United States stopped being the main soybean supplier and was replaced by Brazil.

**Figure 11. Source of the Spanish soybean imports (1998-2014)**




Source: Datacomex, 1998-2014

### 3.2. Soybean meal

Soybeans are a source of protein and oil, as mentioned above. Unprocessed soybeans can be used directly to feed ruminants, although they are normally processed to produce oil. This oil is then used directly for human feeding or its remains (soybean meal, also known as cake and solid remains produced after the extraction of soy oil, TARIC 2304 classification) are used for animal feeding. The protein content of soybean meal is relatively high, as shown in Table 5. Such a high protein content together with the fact that soybean meal can be consumed by animals directly make this a product of a high value for the fodder sector.

**Table 5. Sources of protein for animal feeding**

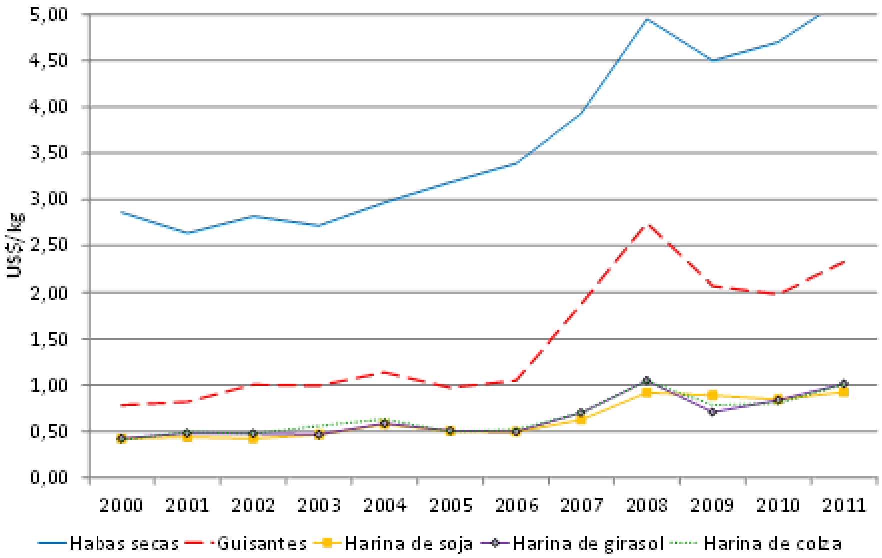
| Product | Protein content (%) |
|---|---|
| **Soybean** | 35 |
| **Soybean meal** | 44-52 |
| **Peas and broad beans** | 20-25 |
| **Lupin beans** | 38-40 |
| **Sunflower oil** | 28-36 |

Sources: FEDNA website http://www.fundacionfedna.org/concentrados_proteina_vegetal; Guerrero (1999); Jones et al. (2014)

Soybean meal also has nutritious properties. It has high quantities of essential amino acids and low levels of anti-nutritious factors that could inhibit growth (Jones et al., 2014). Soybean meal has a low fibre content, which is important when feeding young animals, since it facilitates the absorption of nutrients (Jones et al., 2014).

A crucial characteristics that fosters the use of soybean meal when manufacturing fodder is its price when compared to the price of other substitutes, also taking into account its protein content. To this end, in terms of "protein cost", soybean meal is cheaper than other sources of protein (Jones et al., 2014). Figure 12 shows the price per kg of protein for different imports of the European Union during the 2000-2011 period. This figure shows that even though soy is cheaper than other products in historical terms, both sunflower and rapeseed can be competitive in terms of the price of protein when compared to soy. In fact, rapeseed, sunflower and pea meal have been considered in studies as replacements of soy in terms of the source of proteins for the production of pig and poultry fodder (Nowicki et al., 2010).

**Figure 12. Prices of protein derived from various products**



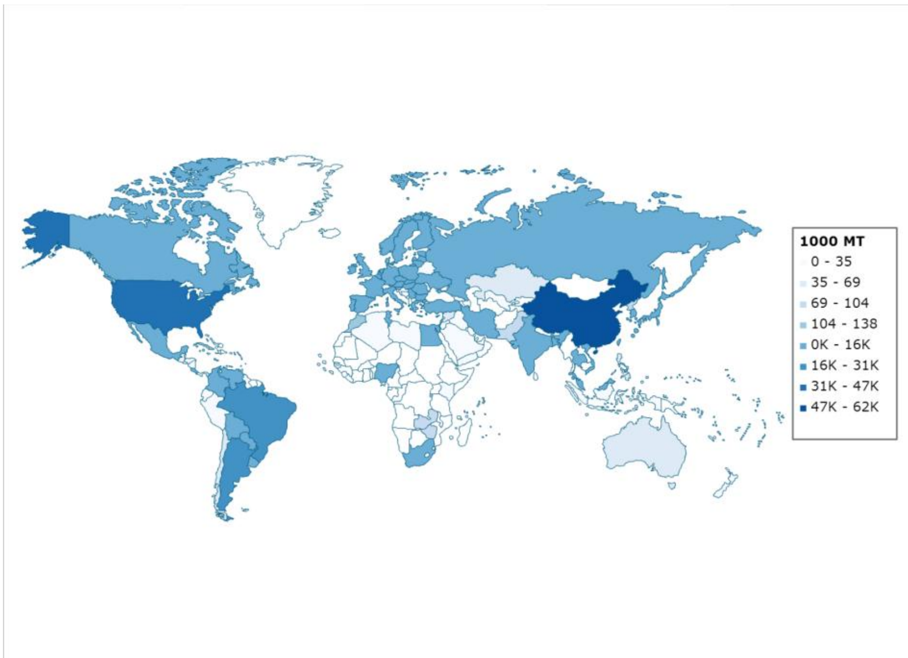

Source: Developed by the author with USDA

Finally, another characteristic of soybean meal is the consistency of the protein content in different soybean meal batches, which helps maintain the quality in the production of fodder, as well as the limited number of protein content quality tests that must be carried out by fodder manufacturers and the use of additives that help balance the rations (Jones et al., 2014).

### *3.2.1. Global production and importation of soybean meal*

Figure 13 and Table 6 show the global distribution of soybean production and its exports and imports. The figure shows that the main global producers are China, the United States, Argentina and Brazil.

**Figure 13. Distribution of the worldwide production of soybean meal in 2014**




Source: USDA data (map prepared by www.indexmundi.com)

Table 6. Soybean meal: Production, exports and imports, by the main producers

| Country | Production (million t) (2014) | Global weight in production (%) | Soybean meal exports Thousands t (%) (2009-2011) | Soybean meal imports Thousands t (2009-2011) | GM soy cultivation | Net exporter |
|---|---|---|---|---|---|---|
| China | 59.0 | 29 | 855 (1.4%) | 247 | No | Yes |
| Unites States | 39.1 | 20 | 7,578 (19.4%) | 94 | Yes | Yes |
| Argentina | 30.4 | 15 | 24,461 (80.5%) | 2 | Yes | Yes |
| Brazil | 29.0 | 14 | 13,426 (46.30%) | 36 | Yes | Yes |
| European Union | 6.5 | 5 | 521 (4.9%) | 28,765 | No | No |
| India | 6.7 | 3 | 4,290 (64%) | 0.5 | No | Yes |
| Mexico | 3.3 | 2 | 7 (0.0%) | 980 | Yes | No |
| Paraguay | 3.2 | 1 | 1,066 (48.5%) | 0 | Yes | Yes |
| Russia | 2.7 | 1 | 16 (0.0%) | 448 | No | No |
| Bolivia | 1.8 | 1 | 1,028 (57.1%) | 0 | Yes | Yes |
| Japan | 1.5 | 1 | 0.1 (0.0%) | 2,102 | No | No |
| Egypt | 1.5 | 1 | 0.5 (0.0%) | 507 | No | No |
| Canada | 1.3 | 1 | 94 (7.2%) | 1,072 | Yes | No |
| Thailand | 1.2 | 1 | 0.1 (0.0%) | 2,364 | No | No |
| Vietnam | 1.0 | 1 | 6 (0.6%) | 2,630 | No | No |
| Ukraine | 0.8 | 0 | 2 (0.3%) | 57 | No | No |
| Korea | 0.8 | 0 | 77 (9.6%) | 24 | No | Yes |
| South Africa | 0.6 | 0 | 8 (1.3%) | 895 | Yes | No |
| Turkey | 0.5 | 0 | 7 (1.4%) | 434 | No | No |
| *World* | *201* | | | | | |

Sources: USDA and FAOstat

As regards the trade of soybean meal, even though China is in the first position as the largest soybean meal producer, its position drops in relation to its importance in the exports of this product. Therefore, the table shows that the main exporters, in order of importance, are Argentina, Brazil, United States, India and Paraguay.

As regards the soybean meal imports, the table shows that the European Union is the main global importer, followed by far by Vietnam and Japan, thus playing a vital role in the international market of this product.

**Table 7. Main global soybean meal importers**

| Country | Soybean meal imports, thousand t (annual average, 2009-2011) | Weight in global importations (%) | Cumulative weight in global importations (%) |
|---|---|---|---|
| **European Union** | 28,765 | 47.4 | 47.4 |
| **Vietnam** | 2,630 | 4.3 | 56.3 |
| **Japan** | 2,102 | 3.5 | 63.6 |
| **Korea** | 1,665 | 2.7 | 66.4 |
| **Iran** | 1,505 | 2.5 | 68.9 |
| **The Philippine Islands** | 1,432 | 2.4 | 71.2 |
| **Canada** | 1,072 | 1.8 | 73.0 |
| **Malaysia** | 1,024 | 1.7 | 74.7 |
| **Venezuela** | 1,015 | 1.7 | 76.3 |
| **Mexico** | 980 | 1.6 | 78.0 |
| **Peru** | 938 | 1.5 | 79.5 |
| **Algeria** | 930 | 1.5 | 81.0 |
| **Colombia** | 910 | 1.5 | 82.5 |
| **South Africa** | 895 | 1.5 | 84.0 |
| **Ecuador** | 533 | 0.9 | 84.9 |
| **Syria** | 510 | 0.8 | 85.7 |
| **Egypt** | 507 | 0.8 | 86.6 |
| **World** | *60,625* | | |

Source: FAOstat

### *3.2.2. Production and importation of soybean meal in the European Union*

In the European Union, the main importer of soybean meal is the Netherlands (Table 8). As mentioned above, this is due to the fact that the Netherlands play a very important role as the point of access of soy into Europe, which is then redistributed to other European countries. The table shows that Spain imports around 2.3 million tonnes of soybean meal per year.

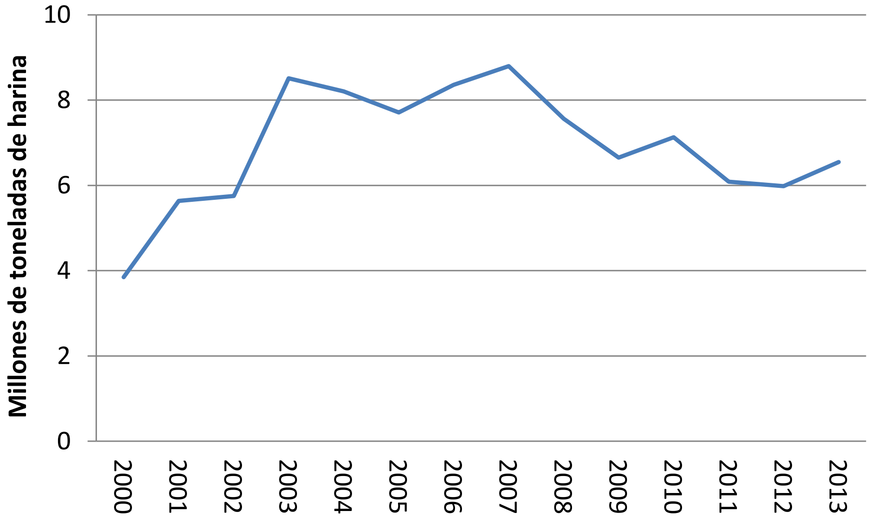
**Table 8. Main soybean meal importers of the European Union**

| Country | Soybean meal imports, thousand t (annual average, 2009-2011) | Weight in EU importations-27 | Weight in global importations |
|---|---|---|---|
| **The Netherlands** | 5,304 | 18.4 | 8.7 |
| **France** | 3,610 | 12.5 | 6.0 |
| **Germany** | 3,397 | 11.8 | 5.6 |
| **Spain** | 2,362 | 8.2 | 3.9 |
| **Italy** | 2,295 | 8.0 | 3.8 |
| **The United Kingdom** | 2,031 | 7.1 | 3.4 |
| **Poland** | 1,868 | 6.5 | 3.1 |
| **Denmark** | 1,598 | 5.6 | 2.6 |
| **Belgium** | 1,322 | 4.6 | 2.2 |
| **Slovenia** | 877 | 3.0 | 1.4 |
| **Hungary** | 602 | 2.1 | 1.0 |
| **Romania** | 453 | 1.6 | 0.7 |
| **Austria** | 415 | 1.4 | 0.7 |
| **Ireland** | 395 | 1.4 | 0.7 |
| **Greece** | 349 | 1.2 | 0.6 |
| **Sweden** | 253 | 0.9 | 0.4 |
| **Portugal** | 215 | 0.7 | 0.4 |
| **Finland** | 158 | 0.5 | 0.3 |
| **Lithuania** | 146 | 0.5 | 0.2 |
| **European Union** | *28,765* | | |
| **World** | *60,625* | | |

Source: FAOstat

As regards the internal production of soybean meal in the EU-27, Figure 14 shows that the internal production of this product during the 2003-2007 period was approximately 8 million tonnes per year, although this figure has dropped since 2008. Currently, the largest producers are Germany (35%), Italy (19%) and Portugal (9%).

**Figure 14. Production of soybean meal in the EU (2000-2014)**

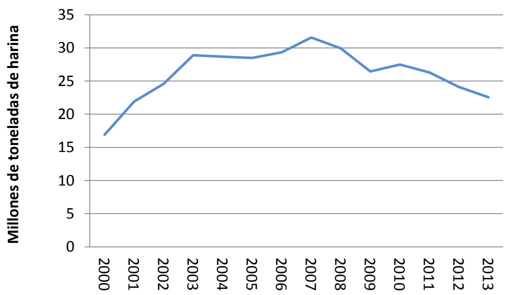



Source: Developed by the author with Eurostat data (2000-2013)

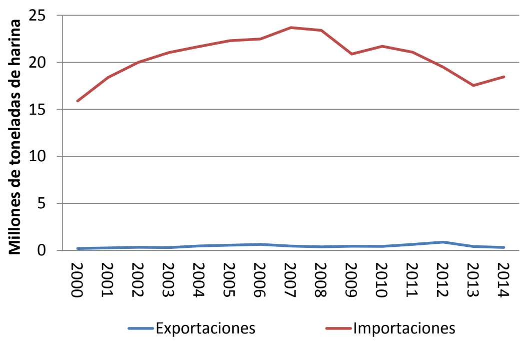
The internal demand for soybean meal in the EU-27 exceeded 14.5 million tonnes in 2014. However, such a demand has suffered a downward trend since 2007, as in the case of internal production. However, Figures 14 and 15a show that the internal production[4] is insufficient to cover the demand of the internal market and, therefore, importations of this product are required.

**Figure 15. Internal demand, imports and exports of soybean meal in the EU (2000-2014)**

**15a. Internal demand (million t)**




**15b. Foreign trade (million t)**




Source: Developed by the author with Eurostat (2000-2013) and Datacomex (2000-2014)

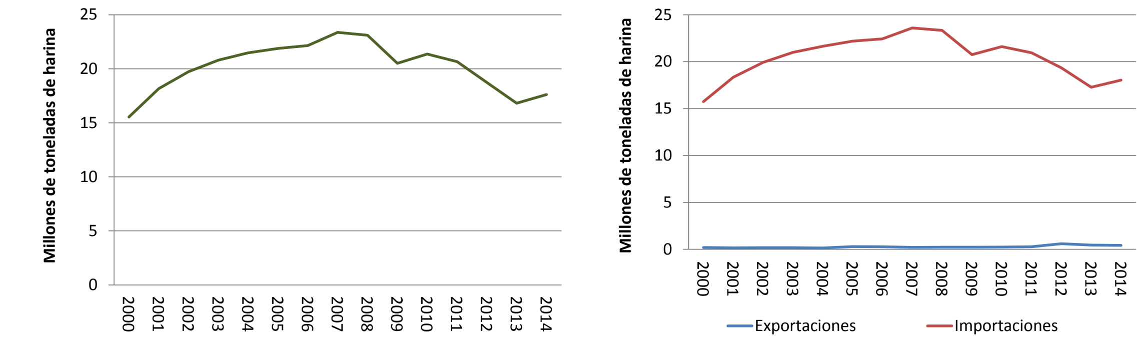
[4] The Spanish internal production of soybeans is lower than the internal production of soybean meal, so that soybeans imported by Spain are used to produce soybean meal by the Spanish milling industry.

### *3.2.3. Production and importation of soybean meal in Spain*

In Spain, the internal production of soybean meal is almost non-existent, whereby imports are required to satisfy the internal demand (see Figure 16).

**Figure 16. Internal demand, imports and exports of soybean meal in Spain (2000-2014)**

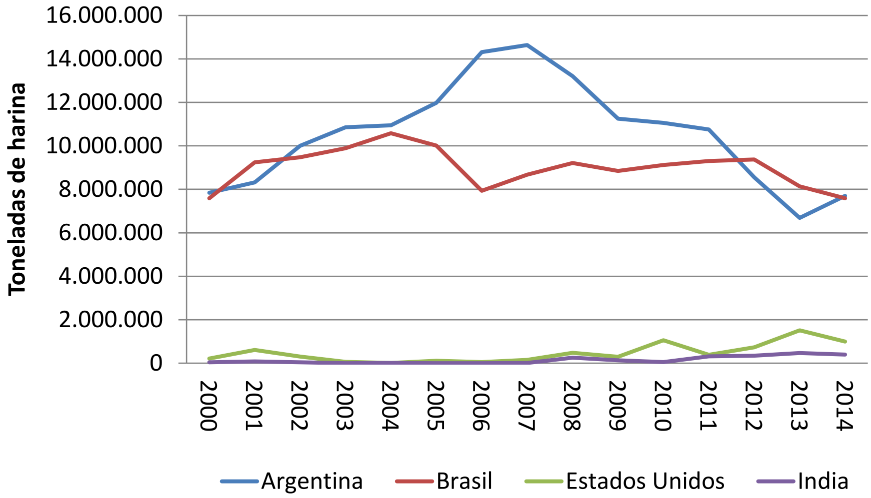
| **16a. Internal demand (million t)** | **16b. Trade (million t)** |
| --- | --- |




Source: Developed by the author with Eurostat data (2000-2013) and Datacomex data (2000-2014)

Figure 17 shows that the main soybean meal suppliers in 2014 were Argentina (42.7%), Brazil (42.1%) and, to a lesser extent, the United States (5.5%) and India (2.2%).

**Figure 17. Main countries supplying soybean meal to Spain (2000-2014)**

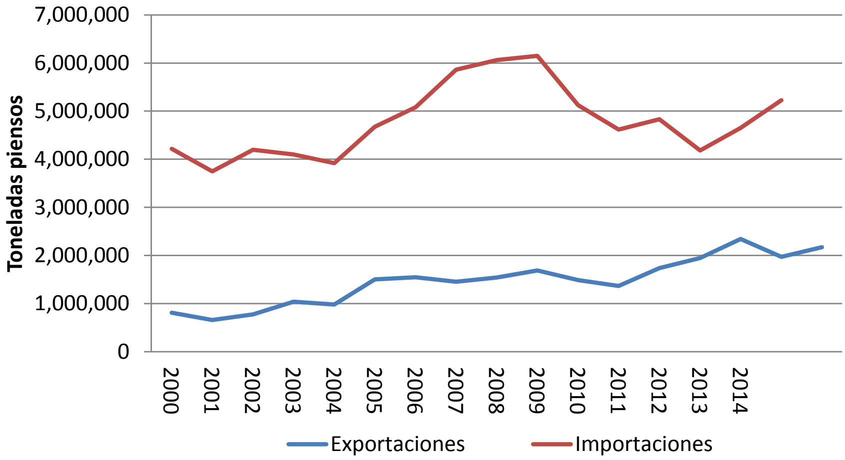



Source: Developed by the author with Datacomex data (2000-2014)

### 3.3. Fodder

In addition to the importance of soybean meal and soybeans in the fodder sector, Spain also imports ready-made products, which are also produced with soy. Therefore, Spain has a shortage in the supply of fodder to cover the demand of the whole livestock farming and poultry industry and, as a result, needs to import these goods, as shown in Figure 18.

**Figure 18. Fodder imports and exports in Spain (2000-2014)**




Source: Developed by the author with Datacomex data (2000-2014)

The main suppliers of the Spanish fodder market during the 2000-2014 period were Argentina (48.4%), the United States (12.6%), Brazil (10.3%) and France (8.0%). The high dependence of Spain on countries such as Argentina, Brazil or the United States, on the supply of soy and derived products is evident.

To sum up, soy and, in particular, soybean meal, is a very important product in animal feeding. Its high protein and fibre content and its nutritive properties, in combination with competitive prices when compared to those of alternative products used as a source of protein, make soy a key product for the fodder and livestock farming industries.

## 4. Estimation of the economic impact of importing GM soy during the 2000-2014 period

The economic impact of importing GM soy during the 2000-2014 period has been estimated. To do so, it is assumed that soy imported from non-GM soy producing countries would have been a viable alternative during the period studied. This study has considered that India and Ukraine[5] will act as the suppliers of soybeans. In the case of soybean meal, it is assumed that India would supply enough soybeans to cover the Spanish demand.

Two different scenarios have been simulated to estimate the economic impact of an increase in the replacement of GM soy imports by conventional soy imports in Spain during the 2000-2014 period: a scenario for soybeans and a scenario for soybean meal, with the following assumptions:

*Scenario 1 (soybeans)*. The following is assumed in this scenario: (1) countries exporting GM soybeans to Spain and Europe have not changed to the production of non-GM soy due to the high demand of third countries and to the complexities associated with changing to a different crop for producers, such as the cost of cultivating and segregating new crops; (2) India and Ukraine, as the main net exporting countries, have contributed to covering the demand for non-GM soybeans in Spain; (3) a 291% increase in the price of soybeans as compared to the base price during the whole period is assumed[6]; (4) prices have been deflated using the FAO's food index.

*Scenario 2 (soybean meal)*. The following is assumed in this scenario: (1) countries exporting GM soybeans to Spain and Europe have not changed to the production of non-GM soy due to the high demand of third countries and to the complexities associated with changing to a different crop for producers, such as the cost of cultivating and segregating new crops; (2) India, as the main net exporting country, has contributed to covering the demand for non-GM soybean meal in Spain; (3) a 301% increase in the price of soybean meal as compared to the base price during the whole period is assumed[7]; (4) prices have been deflated using the FAO's food index; (5) Countries that do not produce GM soy are considered as GM soybean meal exporting countries.

Table 9 shows the results of the simulations for soybeans and soybean meal. The table shows the estimated economic impact of changing from importing GM soybeans to importing conventional soy during the 2000-2014 period. The "base" columns show the annual cost of importing GM soy in thousands of millions of euros while the "SIM" column indicates the costs associated with each scenario. According to the assumptions described above, the estimated impact would be €33,535M. The table also shows the estimates of the economic impact after the move to importing GM soybean meal from conventional soybean meal during the same period. The estimated impact would be €21,060M. It is important to indicate that this second estimate is a

[5] Table 2 shows the 22 main soy producing countries, which represent 99.1% of the average production during the 2009-2014 period. Out of these countries, only India, Ukraine, Nigeria, Serbia and Uganda (net exporters) would be capable of supplying enough soybeans to cover the Spanish demand.
[6] This increase in price is estimated in other sections of this study later on.
[7] This increase in price is estimated in other sections of this study later on.

sub-estimate of the impact, since conventional soybean meal exporting countries might be actually exporting soybean meal extracted from the imports of countries that produce GM soybeans. The total economic impact of the replacement of GM soy with conventional soy during the 2000-2014 period would have been €54,595M.

**Table 9. Results of the simulations**

| | Soybean base (thousands of millions of euros) | Soybeans (thousands of millions of euros) | Soybean meal base (thousands of millions of euros) | Soybean meal (thousands of millions of euros) |
|---|---|---|---|---|
| **2000** | 0.645 | 2.128 | 0.512 | 2.055 |
| **2001** | 0.743 | 3.682 | 0.521 | 2.090 |
| **2002** | 0.824 | 3.264 | 0.621 | 2.490 |
| **2003** | 0.712 | 3.084 | 0.556 | 2.231 |
| **2004** | 0.557 | 2.637 | 0.642 | 2.573 |
| **2005** | 0.474 | 2.528 | 0.524 | 2.100 |
| **2006** | 0.348 | 2.133 | 0.521 | 2.086 |
| **2007** | 0.429 | 2.013 | 0.516 | 2.065 |
| **2008** | 0.725 | 3.299 | 0.607 | 2.435 |
| **2009** | 0.490 | 2.431 | 0.395 | 1.584 |
| **2010** | 0.492 | 2.569 | 0.286 | 1.148 |
| **2011** | 0.592 | 2.685 | 0.301 | 1.208 |
| **2012** | 0.707 | 3.126 | 0.322 | 1.290 |
| **2013** | 0.716 | 3.478 | 0.276 | 1.106 |
| **2014** | 0.763 | 3.694 | 0.399 | 1.599 |

Source: Developed by the author

It is worth mentioning that the average of all soy exports of net non-GM soy exporting countries reached 585,000 tonnes between 2009 and 2011, out of which a percentage was exported to Europe. Such a percentage is insufficient to cover the European and Spanish demand for soy. It is important to take into account that should the EU restrict GM soybean imports, a demand of 14.6M tonnes would have to be covered at the European level. In addition, the global production of non-GM soybeans would have to double, since the average annual production during the 2009-2013 period was 12.2M tonnes.

This means that either (a) the global production of non-GM soy would have to be doubled (increasing the current exportation of non-GM soybeans twentyfold) and fully exported to the EU-27 to cover this demand; or (b) the protein obtained from soybeans would have to be replaced with the protein of other alternative crops, such as peas, broad beans, lupin beans or sunflower (something that was seen not to be previously viable in Spain); or (c) a combination of the two options described above.

## 5. Assessment of the replacement of genetically modified soy imports

The alternatives for the replacement of Spanish genetically modified soy imports that have been assessed are as follows: 1) replacement of these imports with conventional soy imports; 2) increasing the national production of crops that can be used as a source of proteins (peas and broad beans) and that, therefore, can be used to feed cattle with no need for excessive processing (Jones et al., 2014); to this end, for example, lupin beans with supplements could be used to feed pigs and poultry (Jones et al, 2014); and 3) oilseed meal, such as sunflower seed meal.

In the next sections the possible alternatives mentioned are studied: 1) Assessment of the replacement of GM soy imports by non-GM soy imports; 2) Assessment of the replacement of GM soy imports with an increase in the national production of alternative crops; 3) Assessment of the replacement of GM soy imports with alternative oilseed meals, in particular, the case of sunflower seeds will be studied.

The assessment of the replacement of GM soy imports by an increase in the national production of alternative crops (alternative 2) is performed with the calculation of production and the surface area required to cover the protein requirements associated with the Spanish non-GM soy imports, with the cultivation of different alternatives to soy to obtain protein, as is the case of sunflower, broad beans, peas and lupin beans.

The joint impact of the increase in the demand of conventional soy (imports) on the price of the fodder industry's products is then assessed with an analysis of the input-output table. The implications of these increases in the price of raw materials in the fodder and livestock farming sectors will be studied in the next section.

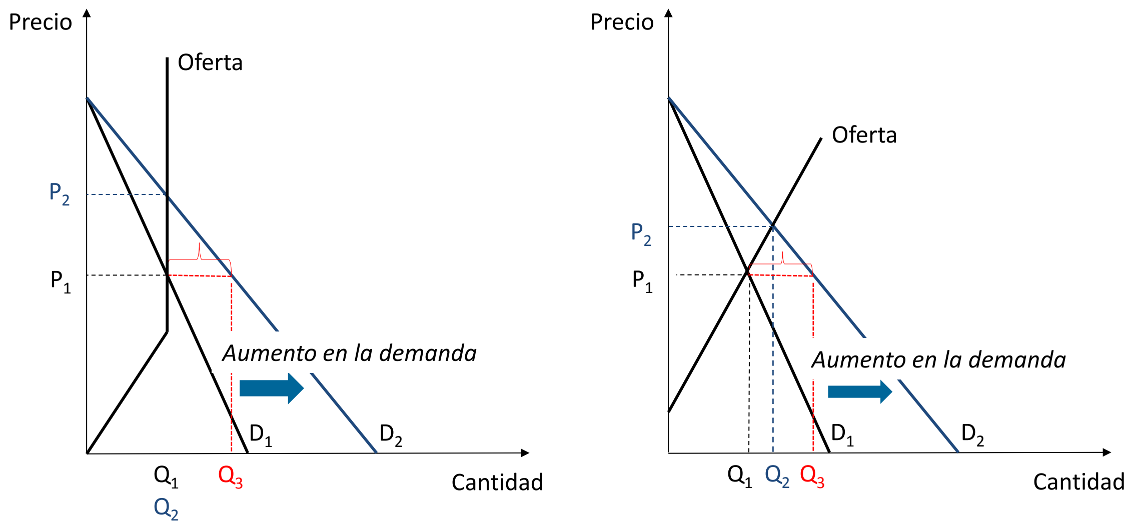
## 6. Assessment of the replacement of GM soybean imports by non-GM soybean imports

This economic analysis studies the impact of the increase in the demand of non-GM soy by Europe on prices, derived from the impossibility to purchase GM soy, since access to GM soy has been restricted by the EU. To do so, the global non-GM soybean and soybean meal markets are studied. In particular, the impact of an increase in the demand of these markets is analysed, derived from the EU's need to access a product that has not been genetically modified (broad beans or soybean meal) as a consequence of blocked access to GM soy and soybean meal markets. Such an impact is studied assuming a series of assumptions related to the demand and supply curves of these markets in the short and long-term. These analyses will then be used to estimate the impact of these changes in the demand on the price of non-GM soybean and soybean meal imports in the EU in the short-term.

Figure 19 focuses on the impact on the global non-GM soybean market prices, although this analysis covers both the soybean and soybean meal markets in the short and long-term (Figures 19a and 19b).

**Figure 19. Increase in the market demand of non-GM soy in the short and long-term**

**(a) Short-term non-GM soybean** **(b) Long-term non-GM soybean**



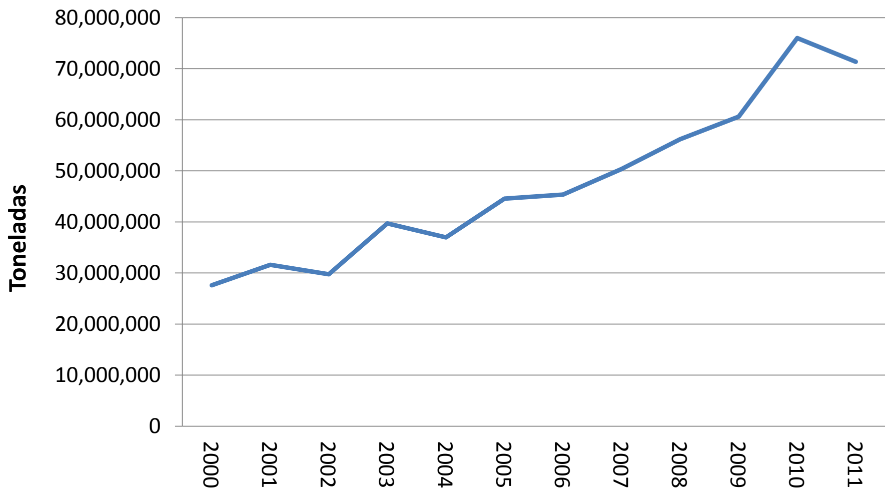

Source: Developed by the author

The short-term situation shown in Figure 19 (a) refers to unsatisfied demand (quantity $Q_3$-$Q_1$ is not satisfied by the market for price $P_1$). In the short-term, the conventional soy supply (soybeans and soybean meal) is rigid. Therefore, the quantity supplied cannot increase to satisfy the demand ($Q_3$-$Q_1$), mainly due to the problems in replacing GM soy with conventional soy. Such a rigidity in the supply leads to a new equilibrium in the non-GM soy market at a higher price ($P_2$) than the market price of the situation prior to the increase in demand ($P_1$).

The relative weight of the EU in the global market of soybeans (16% of global imports) and soybean meal (47% of global imports) would mean that any change in the EU's demand for soy could have an impact on the distribution of the said supply in the medium and long-term. These impacts on the supply cannot be easily estimated, since not only is the farmers' willingness to change to a different type of crop one of the factors that must be taken into account, but also the costs associated with the segregation of crops to certify the type of soy (GM soy or conventional soy) in GM soy producing countries. This fact could also be responsible for the increase in the quantity of conventional soy produced, leading to the increase in prices, which would be dampened or even dissipated by the costs of production as a consequence of the addition of new costs associated with the segregation of both products.

Therefore, assuming that the conventional soy supply is perfectly inelastic in the short-term, conventional soy prices are expected to increase, but the *production will not cover the increase in European demand*, as shown in Figure 19 (a). Even though the conventional soy supply is relative more elastic in the medium/long-term, *it is also improbable that it will be capable of covering the European demand for conventional soy*, since this would only be achieved with a perfectly elastic supply. It is important to highlight that the medium/long-term supply will also be modified as a consequence of the costs associated with the change in the cultivation and segregation system. Therefore, various factors are relevant in the medium/long-term. Firstly, an increase in the prices of non-GM soy will act as an incentive to increase the production volumes of this crop. Such an increase in production could consolidate more easily in those countries where conventional soy is currently cultivated than in countries where GM soy is cultivated. The change from GM soy to conventional soy not only means that farmers must be willing to modify their crop growing plans and production, but also that an increase in the associated costs of the two crops must be taken into account in those countries where both crops are cultivated, as mentioned above. Predictably, farmers will choose one of these two types of crop, but both options must also contemplate the segregation of crops (separation of GM soy and conventional soy by the purchaser, which will then sell these crops or export them) and their transport. Secondly, the demand of third countries is expected to continue growing (see Figure 20) and this will mean that producing countries for which the EU is not its main importer will not modify their crops in the medium-term.

**Figure 20. Evolution of soybean imports in third countries (2000-2011)**



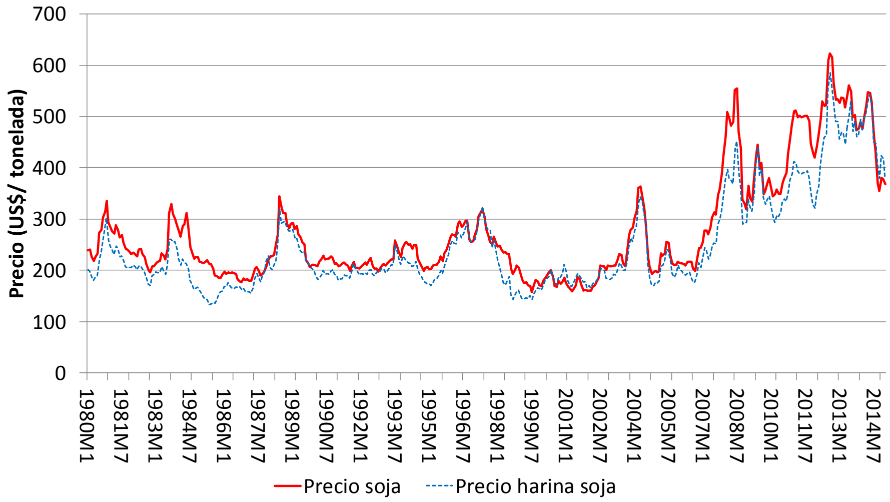

Source: Developed by the author with FAOstat

Therefore, supply might be relatively inelastic in the medium/long-term, which would result in a slightly lower increase in the cost of the price of soy in the medium/long-term than that recorded in the short-term. In this case, a different source of protein must be provided to cover the shortage in supply of the protein derived from soy. Again, such an increase in the demand for an alternative product, such as sunflower, would lead to an increase in its price in the short-term.

### 6.1. The soybean market

The global production of non-GM soybeans is approximately 63 million tonnes, at a price of 491 US$/t[8] . Figure 21 shows the evolution of the global price of soybeans and soybean meal (with a protein content of at least 48%), between 1980 and 2015, portraying the difference in prices before and after 2007[9].

**Figure 21. World price of soybeans and soybean meal (1980-2015)**




Using non-GM soybean price, production, import and export data of the year 2011 (Table 10), it can be concluded that 12.8 million tonnes of GM soybeans and non-GM soybeans were consumed by the EU during 2011. The restrictions to the access of GM soybeans would lead to an increase in the demand for non-GM soy with the purpose of covering such a shortage[10] in the supply of GM soybeans, as mentioned above. Such an

[8] This is the average global price of soy during the 2009-2015 period.

[9] The discussion about whether a price bubble has existed with soy is an open debate and studies show evidence of the presence of such a bubble (Gilbert, 2010; Danders and Irwin, 2011). However, other studies show evidence of the fact that such a bubble is weak (Gutierrez, 2013) or the complete opposite (Areal et al., 2013).

[10] The replacement of the demand of GM soy and non-GM soy for animal feeding can be fully assumed.

increase in the demand would be equivalent to the soy imported from Gm soy producing countries, for a total of approximately 11.5 million tonnes in 2011[11].

**Table 10. Soybean production, imports and exports in the EU during 2011 (t)**

| | GM Soybeans | Non-GM Soybeans |
|---|---|---|
| **Production** | 0 | 1,245,257 |
| **Imports** | 11,501,728 | 140,944 |
| **Exports** | 0 | 78,413 |
| **Total quantity in the European market** | 11,501,728 | 1,307,788 |

Source: Developed by the author with FAOstat

Table 11 shows the production, imports and exports of soybean meal in the EU during 2011. The demand for non-GM soybean meal would grow until it covers the lack of access to GM soybean meal. Such an increase would be equal in quantity to the volume of soybean meal imported from GM soybean meal producing countries, i.e., approximately 20.5 million tonnes in 2011[12].

**Table 11. Soybean meal production, imports and exports in the EU during 2011 (t)**

| | GM Soybean meal | Non-GM Soybean meal |
|---|---|---|
| **Production[13]** | 9,625,000 | 1,075,000 |
| **Imports** | 20,468,728 | 7,959,095 |
| **Exports** | 0 | 652,104 |
| **Total quantity in the European market** | 30,143,728 | 8,381,991 |

Source: Developed by the author with FAOstat; Berk et al (2008); Jones et al. (2014).

[11] This calculation is derived from the data on European imports from GM soy producing countries. It is assumed that all soy imported from these countries is genetically modified, since the levels of adoption of GM soy exceed 90%. Likewise, it is assumed that all soybean imports are used to produce soybean meal.

[12] This calculation is derived from the data on European imports from GM soy producing countries. It is assumed that all soy imported by these countries has been genetically modified. The genetically modified soy adoption levels of these countries exceed 90%.

[13] In 2014, Europe produced 10.7 million tonnes of soybean meal, its raw material mainly being GM soybeans. Taking into account the data about the distribution of soybeans in the European market, it is assumed that approximately 10% would be classified as non-GM soybean meal. To this end, the European non-GM soybean meal production would be estimated at 1,075,000 tonnes, while 9,625,000 would be GM soy.

Under the hypothesis of a change in the implementation of the European policy on GM soy imports that prevents its access to such a crop, this would lead to an increase in the global demand for GM soybeans of 11.5M tonnes (from 63M to 74.5MN tonnes). In the case of the inelastic supply of non-GM soybeans in the short-term, such an increase in the demand could lead to a 291%[14] increase in the prices of non-GM soybeans in the short-term.

### 6.2. The soybean meal market

Assuming the hypothesis mentioned above for soybeans, a 20.5M tonne increase in the global demand for non-GM soybean meal could be generated (from 108M to 128.5M tonnes). In the case of an inelastic supply of non-GM soybean meal in the short-term, such an increase in the quantity would lead to an increase in the estimated price of soybean meal of 301%[15].

### 6.3. Other studies

Different studies about the impact of restricting soy imports from GM soy producing countries on the prices of soy have been prepared during the last few years (Nowicki et al., 2010). Nowicki et al. (2010) studied the impact on the price of soy using different market simulations. Therefore, by simulating a restriction of the EU to soy imported from Argentina, Brazil and the United States, the authors found that a reduction in the soy imports coming from these countries would not be compensated with the increase in European production and the importations of other regions. In particular, there would be a 220% increase in the price of soybeans and 211% in the price of soybean meal.. This study also simulated the case in which the EU restricted the soy imports from all main suppliers in America (Argentina, Brazil, the United States, Paraguay, Canada, Uruguay and Bolivia). In this scenario, Nowicki et al, (2010) highlight that *the conditions required to find a spatial solution of market equilibrium for soy are not met*. In other words, the demand of the EU cannot be covered by the production of other soy producing countries. These authors also highlight that the increase in soybean and soybean meal prices would be much higher than 220% and 211%, respectively. These results, both in terms of the increase in prices and the incapacity to cover the demand, agree with the results of this study.

[14] That is, assuming a -0.053 elasticity of global prices corresponding to net soy exports of the EU (Chantreuil et al, 2008).

[15] That is, assuming a -0.053 elasticity of global prices corresponding to net soy exports of the EU (Chantreuil et al, 2008).

## 7. Assessment of the replacement of GM soy imports by other alternatives

### 7.1. Assessment of the replacement of GM soy imports by an increase in the national production of alternative crops

GM soy imports can be replaced by an increase in the internal production of these crops or by an increase in imports. It must be taken into account that Spanish soybean imports are around 3.0 million tonnes, while soybean meal imports are around 2.3 million tonnes. In addition, the protein content of soybeans is 35% while that of soybean meal is approximately 52%. Therefore, the total demand of protein that must be replaced is 2,306,030 tonnes of protein.

As regards the feasibility of increasing the national production of alternative crops, Table 12 shows the production needed in Spain to cover the protein needs of animal feeding derived from blocking all soy imports. According to these results, it is hard to think that the land used for cultivating crops alternative to soy is a viable alternative, given the vast the cultivation surface required to compensate the lack in protein. Taking into account that the crop-growing surface area used in Spain is 16 million hectares (MAGRAMA, 2014), it can be observed that if the lupin seeds were used as the source of protein, this would require covering practically the whole surface area used to grow crops in Spain, increasing the current cultivated surface area by 2,568 times. In the case of sunflower, more than half of the crop-growing surface would have to be used to grow these crops and the number of hectares would have to be multiplied by 10. In the case of green beans, the surface area would have to be multiplied by 62. Similarly, the surface area for peas would have to be multiplied by 60 and that of dry broad beans by 906. The figures of the increase in surface area are not feasible at all, given the magnitude they represent in relation to the total surface area that can be cultivated in Spain. Likewise, this is not expected to occur only because of the restriction of imports with no changes in the demand for all other crops produced, given the fact that the change of crops is something that the farmer chooses to do voluntarily.

**Table 12. Results of the surface area and production of alternative crops required to replace protein derived from GM soy**

| Product | Average surface area (hectares), 2009-2013 | Average yield (t/hectare), 2009-2013 | Average production (t), 2009-2013 | % Dry matter | Protein content (%) | Cultivated surface area required in Spain (hectares) | Surface area of cultivated land in 2014 (%) | Harvest yield required in Spain (t) |
|---|---|---|---|---|---|---|---|---|
| **Soybeans** | 743 | 1.1 | 1,776 | 90 | 35 | 3,062,670 | 18.2 | 7,320,730 |
| **Lupin beans** | 6,174 | 0.6 | 3,729 | 86 | 28 | 15,855,601 | 94.4 | 9,576,537 |
| **Sunflower** | 804,438 | 1.1 | 899,022 | 88 | 28 | 8,374,262 | 49.8 | 9,358,889 |
| **Peas** | 177,756 | 1.1 | 193,474 | 86 | 23 | 10,711,298 | 63.7 | 11,658,440 |
| **Dried soybeans** | 7,040 | 1.6 | 11,440 | 86 | 26 | 6,383,464 | 38.0 | 10,313,129 |
| **Linseed** | 6,818 | 1.2 | 8,046 | 90 | 18.5 | | | |
| **Wheat** | 1,919,256 | 3.1 | 5,975,105 | 86 | 10 | | | |
| **Oats** | 490,302 | 1.9 | 943,204 | 86 | 9.4 | | | |
| **Barley** | 2,811,223 | 2.8 | 7,954,380 | 86 | 9 | | | |
| **Rye** | 146,734 | 2.0 | 289,144 | 87 | 8.5 | | | |

Source: Developed by the author

### 7.2. Assessment of the replacement of GM soy imports by alternative oilmeals

Other alternatives to the replacement of a shortage in the offer of protein for its use in the production of fodder obtained from non-GM soy could be the importation of crops that replace soy. One of the most competitive alternatives in terms of price is the protein obtained from sunflower meal, as mentioned above. In this case, for example, an increase in the imports of sunflower seeds that can cover the protein requirements of animal feeding will be analysed. 9.4M tonnes of sunflower would be needed to cover the protein needs equivalent to 3.0M tonnes of soybeans and 2.3M tonnes of soybean meal. However, the sum of exports of the 20 main producing countries is only 3.8M tonnes. Therefore, given the current conditions, it would not be viable to replace soy with sunflower as a source of protein for animal feeding.

A similar analysis to that of the replacement of soy imports is used to calculate the impact of an increase in the demand of sunflower on its price. This would lead to an increase in the global demand for sunflower of 9.4M tonnes (from 37.4 to 46.8M tonnes, resulting in an 25% increase in the global production of sunflower). Taking into account that the average global yield of sunflower is 1.5 tonnes/hectare, the surface used to grow this crop would have to be increased globally by 6.3 million hectares[16]. To this end, it is important to highlight that in the EU there are no intentions to develop large-scale domestic production systems with protein-rich plants and different studies have estimated that only 10 to 20% of European soybean and soybean meal imports could be replaced (Popp et al., 2013).

With an inelastic supply of sunflower in the short-term, the increase in demand would lead to an 82%[17] increase in the prices of sunflower in the short-term. In the medium/long-term, the increase in prices could result in an increase in the supply, which could slightly reduce the prices recorded in the short-term. A detailed study of the global supply of sunflower would have to be prepared to estimate the effect of this on the price of sunflower.

[16] The average global surface area used to grow sunflowers during the 2009-2013 period was 24,702,598 (FAOstat).

[17] That is, assuming a -0.244 elasticity of global prices corresponding to net sunflower exports of the EU (Chantreuil et al, 2008). The following is assumed as the average price of sunflower imported by the EU since 2009-2011: 623.09 US$.

**Table 13. Sunflower meal production, imports and exports in the EU during 2011 (t)**

| | Sunflower meal |
|---|---|
| **Production (t)** | 8,533,085 |
| **Imports** | 2,996,482 |
| **Exports** | 3,548,554 |
| **Total quantity in the European market** | 7,981,013 |
| **Quantity required** | 9,400,000 |

Source: Developed by the author with FAOstat

## 8. Impact of the increase in the price of soy on the fodder industry and on farmers

This section analyses the importance of the change in soy prices for the fodder industry, taking into account its impact on the cost of manufacturing fodder, as well as on its impact on the cost of production for the farmer. In the case of the latter, the impacts on the poultry, egg, pig and cattle sectors are analysed.

### 8.1. Impact on the fodder industry

The animal feeding industry is a sub-sector of the Spanish food and beverages industry, which is made up of a total of 28,762 companies that employed 439,760 employees in 2013 (FIAB, 2013)[18]. The 2013 turnover of this industry was €88,673M.

During 2012, the animal feeding industry contributed to the food industry with an €8,900M turnover and 95,000 employees, representing 10% of the total turnover and 22% of the number of employees of the food industry (FIAB, 2013).

The fodder manufacturing sector mainly uses cereals and other crops, as well as products derived from the food and beverage industry as its raw materials, with which it produces a variety of rations (different compositions) for different animals (Jones et al., 2014). Soybean meal is the most important protein for animal feeding, while other alternative sources of protein are in decline, such as peas and dry broad beans. Therefore, it is estimated that soy can represent 20% of the total quantity of the ingredients used in fodder rations (Jones et al., 2014).

The average ratio of the use of soybean meal in fodder in the EU is approximately 13% (Popp et al., 2013). However, this ratio varies according to the type of cattle fed with

[18] http://www.fiab.es/es/industria/industria.asp

this type of fodder. For example, Table 14[19] shows the weight of soybean meal in the fodder for different animals, according to the estimates of Jones et al. (2014) in relation to the weight of the different ingredients used to manufacture these types of fodder in Great Britain.

**Table 14. Mean ratio of the different quantities of ingredients used in fodder by type of livestock farming industry (%)**

| | Cattle | Pig | Birds |
|---|---|---|---|
| **Soybeans** | 11.0 | 12.0 | 19.1 |
| **Peas and broad beans** | 1.5 | 2.6 | 0.0 |
| **Lupin beans** | 0 | 0.5 | 0.0 |
| **Oilmeals** | 26.3 | 4.3 | 0.2 |
| **Dry distillers grain** | 8.0 | 0.0 | 0.0 |

Source: Jones et al., 2014

Taking into account the information provided by Jones et al. (2014) and the prices of ingredients, the weight of each ingredient in the total cost of the ingredients used to manufacture fodder can be estimated (Table 15).

**Table 15. Mean ratio of the different ingredients in the total cost of fodder by type of livestock farming industry (%)**

| | Cattle | Pig | Birds |
|---|---|---|---|
| **Soybean products** | 16.7 | 18.2 | 29.0 |
| **Peas and broad beans** | 1.4 | 2.4 | 0.0 |
| **Lupin beans** | 0.0 | 0.5 | 0.0 |
| **Oilmeals[20]** | 26.2 | 4.3 | 0.2 |
| **Dry distillers grain** | 8.0 | 0.0 | 0.0 |

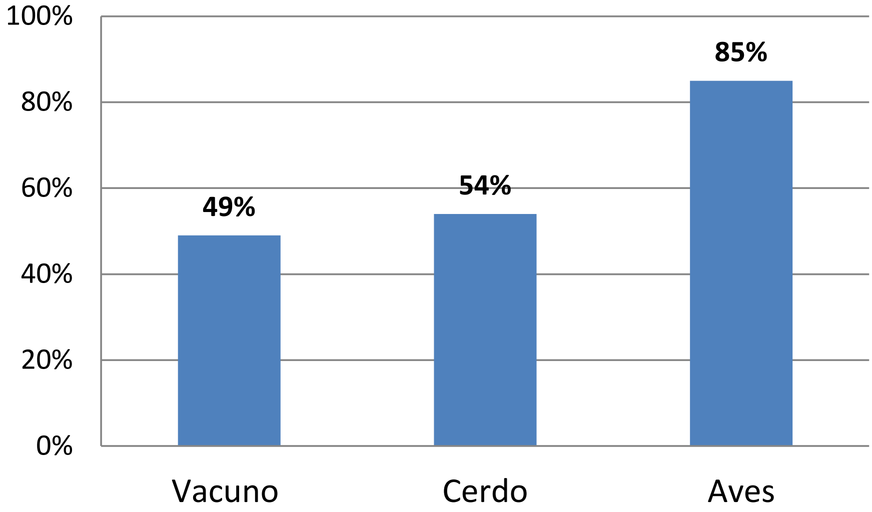
Source: Developed by the author with Jones et al., 2014

[19] Other ingredients of the different types of fodder are not included in the table, such as barley, wheat or corn.

[20] Does not include soybean meal

The impact of the increase in the price of soy on the ingredients used to manufacture fodder can be estimated with the weight of the ingredients of fodder in the cost ratio of the fodder ingredients shown in the previous table[21]. Therefore, a 294%[22] increase in the price of soy, as estimated in the previous section, would lead to a 49%, 54% and 85% increase in the cost of the ingredients used to manufacture cattle, pig and poultry fodder, respectively (see Figure 22).

**Figure 22. Increase in the cost of fodder production ingredients (%)**




### *8.1.1. Analysis of the input-output table of the Spanish economy*

The input-output tables of the Spanish economy (2005, National Statistics Institute) have been used to assess the effect of a modification in the soy prices on the products of different sectors and, in particular, on the prices of products produced by the fodder industry. This method can be used to estimate the impact generated by a change in the price of soy imports on the price of fodder, taking into account all production factors that are part of the production process.

The transactions table is used as the base of the input-output system, which represents an extended version of the national accounting, including all transactions and the flow of goods and services between different industries of the economy.

[21] Such a direct estimation does not take into account the weight of other fodder manufacturing factors in the manufacturing of fodder, such as the cost of labour, machinery or acquisition of other inputs to other industries.

[22] A 294% increase in prices is the average increase in the prices of soybeans and soybean meals, weighted by the weight of Spanish soybean and soybean meal imports.

The input-output model can be represented with the following expression:

$$X_j = \sum_i a_{ij} X_j + V_j \qquad [1]$$

where $X_j$ represents the production vale of the sector j , which covers the cost of acquisitions to other sectors in a fixed proportion $a_i$, $\sum_i a_{ij} X_j$., plus the cost of the primary input $V_j$. The primary input cost is the cost of imports while manufacturing a product, plus the costs of labour and added value. This expression [1] measures the flow of transactions (price x quantity) in millions of euros. The following expression is obtained by multiplying the expression [1] by the prices of the industry's products j , $P_j$, and dividing it by the sector production value $X_j$ :

$$P_j = \sum_i a_{ij} P_j + v_j \qquad [2]$$

where $v_j = \frac{V_j}{X_j}$ is the primary input cost per unit of production. The expression [2] is very useful, since it can be used to obtain the unit price to primary production input cost ratio (imports, costs of labour and added value).

The impact on the prices of industry products can be estimated, assuming a 291% increase in the prices of soybean imports and a 301% increase in the price of soybean meal imports. In 2014, Spain imported a total of 5.29M tonnes of soy products, 3.462M tonnes of soybeans and 1.828M tonnes of soybean meal. Taking this into account, an increase in the cost of imports of the Spanish fodder sector is assumed, according to the weighted mean of the increases in the prices of soybeans and soybean meal (294%).

Table 16 shows the results of the input-output analysis of the 10 main affected industries, indicating a moderate impact on prices. Such a moderate effect is due to the weight of imports on the fodder industry, approximately 18% of the industry supply at basic prices. Therefore, the main impact is on the fodder sector (included in the branch of other food industries), with an 11.3% increase in the price of products, followed by an impact on the agriculture, livestock farming and game sectors, with a 1.6% increase in the price of their products. The dairy and meat industries would also be affected by the 1.2% and 0.9% increase in the prices of their products, respectively.

**Table 16. Increase in the price of products by industry**

| Industry | Increase in the price of products (%) |
|---|---|
| Other food industries | 11.3 |
| Agriculture, livestock farming and game | 1.6 |
| Dairy product industries | 1.2 |
| Beverages | 1.0 |
| Meat industry | 0.9 |
| Restoration | 0.7 |
| Accommodation | 0.3 |
| Maritime transport | 0.2 |
| Healthcare and market social services | 0.1 |
| Tobacco industry | 0.1 |

Source: Developed by the author

## 8.2. Impact on livestock farmers

This section estimates the impact of an increase in the price of soy on the different livestock farming production rates: eggs, poultry, cattle and pigs.

### *8.2.1. Eggs*

The Spanish and European egg production industry must comply with the European legislation for the protection of the environment, animal welfare and food safety. The costs associated with such a legislation represent over 15% of the total cost of production of eggs, making the European industry less competitive in terms of prices than the industries of other countries that do not have a similar legislation (Van Horne, 2014).

The average price of fodder for the production of eggs is 29.9€/100kg and the weight of the cost of fodder is approximately 63% of the total costs of production in Spain (Table 17; Van Horne, 2014).

**Table 17. Primary cost of production (in cents per Kg of eggs) in Spain during 2013.**

| | |
|---|---|
| Total costs, including costs of labour | 97.8 |
| Total costs, excluding costs of labour | 94.3 |
| Cost of a laying hen (20 weeks) | 19.9 |
| Cost of fodder | 61.9 |
| Other costs | 5.7 |
| Cost of labour | 3.5 |
| Livestock upkeep costs | 7.8 |
| General costs | 0.9 |
| Costs of waste/manure | -0.2 |
| Revenues invested in chickens | -1.7 |

Source: Developed by the author with Van Horne data (20002014)

The results show that, in the case of the production of eggs, a 294% increase in the price of soy would result in an 85% increase in the cost of the ingredients used to manufacture fodder for laying hens. Likewise, the 11.3% increase in the cost of fodder would result in a 7.1% increase in the costs of production of eggs.

### *8.2.2. Birds*

The Spanish and European poultry meat production industry must comply with the European legislation for the protection of the environment, animal welfare and food safety. The production of poultry meat in Spain during the year 2012 is shown in Table 18. The total number of poultry farms producing poultry meat in Spain was 39,930, out of which 3,360 had over 5,000 birds, which means that 17.1% of the large poultry farms dedicated to the production of poultry meat are found in Spain (Van Horne and Bondt, 2013). The amount of full-time workers in the Spanish poultry sector in 2012 was estimated to be 28,588 (Van Horne and Bondt, 2013).

**Table 18. Poultry meat production in Spain during 2012 (1,000 t, weight of the carcass)**

| | |
|---|---|
| Chicken processed for the production of meat | 1,063 |
| Turkey | 111 |
| Duck | 6 |
| Other birds | 71 |
| Total | 1,251 |
| % EU-27 | 9.7 |

Source: Van Horne and Bondt (2013)

The average price of fodder used for the production of poultry meat is 34.6 €/100kg. The weight of fodder costs in Spain represents approximately 71% of the total cost of production (Table 19, Van Horne and Bondt, 2013). Therefore, in the case of the production of poultry meat, a 294% increase in the price of soy would result in an 85%

increase in the cost of the ingredients used to manufacture fodder for poultry. An 11.3% increase in the cost of fodder would result in an 8.0% increase in the costs of production of poultry meat.

**Table 19. Primary cost of production (in cents per Kg of the weight of a live animal) in Spain during 2011.**

| | |
|---|---|
| Total costs, including costs of labour | 95.2 |
| Total costs, excluding costs of labour | 92.3 |
| Cost of chicken (1 day) | 12.2 |
| Cost of fodder | 67.4 |
| Other variable costs | 5.8 |
| Cost of labour | 2.9 |
| Livestock upkeep costs | 5.9 |
| General costs | 0.9 |

Source: Van Horne and Bondt (2013)

### *8.2.3. Pork*

The pork sector is the most important livestock sector in Spain representing 34.2% of final livestock production and 12.4% of agricultural production (web MAGRAMA). The pork sector had 51,767 farms in 2013 (INE). The sector also had to adjust to the entry into force of the legislation on animal welfare of porks, mainly due to the requirement to keep sows in groups during a period of gestation (web MAGRAMA).

The weight of fodder in the cost of production of pork represents 70 to 73%[23] of the total cost of production in Spain. Therefore, in the case of the production of pork, a 294% increase in the global prices of soy would result in an increase of approximately 54% of the cost of production of the ingredients used for pig fodder. Therefore, the 11.3% increase in the cost of fodder would result in a 7.9 to 8.2% increase in the costs of production of pork.

### *8.2.4. Cattle*

The beef cattle sector represents 15.35% of final livestock production in Spain being the third largest behind the pig and dairy sector. The sector had 66 987 farms in 2013 (INE). The sector sacrificed a total of 2,219,731 heads in 2013 (MAGRAMA, 2013).

[23] Personal communication with the ANPROGAPOR association.

The weight of fodder in the cost of production of beef, obtained from breeding cows, represents 35 to 45%[24] of the total cost of production in Spain. Therefore, in the case of the production of beef, a 294% increase in the global prices of soy would result in an increase of approximately 49% of the cost of production of the ingredients used for cattle fodder. Therefore, the 11.3% increase in the cost of fodder would result in a 4.0 to 5.1% increase in the costs of production of beef.

Table 20 shows the effects of the increase in price of soy in the cost of production of eggs, poultry meat, beef and pork.

**Table 20. Effects of the increase in price of soybeans on different products**

| | Weight of soy in the cost of fodder ingredients | Increase in the cost of fodder production ingredients | Increase in the price of fodder | Weight of the cost of fodder in the cost of production | Increase in the cost of production |
|---|---|---|---|---|---|
| **Eggs** | 29.0% | 85% | 11.3% | 63% | 7.1% |
| **Poultry meat** | 29.0% | 85% | 11.3% | 71% | 8.0% |
| **Pork** | 18.2% | 54% | 11.3% | 70-73% | 7.9%-8.2% |
| **Beef (breeding cow)** | 16.7% | 49% | 11.3% | 35-45% | 4.0%-5.1% |

[24] Personal communication with the ASOPROVAC association.

## 9. Conclusions

This study has analysed the viability of alternatives to importing genetically modified (GM) soybeans in Spain within the global trade framework. The analysis is based on a potential increase in the demand for conventional soy in the EU, derived from the impossibility to acquire GM soy after access to this type of crop has been restricted.

According to the results of the study, the following is concluded:

1) Soy is a key raw material for the production of fodder, because of its high protein content and the very competitive prices of this protein.
2) Spanish GM soy imports as the alternative to having solely imported conventional soy during the 2000-2014 period have resulted in savings of at least €55,000M. This has been due to the high cost of importing conventional soy and its relatively high price.
3) The attempt to replace GM soy imports with conventional soy would lead to a shortage in the supply of this raw material in the short-term for the fodder manufacturing industry. This industry would have to seek for alternative sources of protein both in Europe and abroad. Previous studies have indicated that there are not intentions to develop large-scale domestic production systems with protein-rich plants, estimating that only 10 to 20% of European soybean and soybean meal imports could be replaced.
4) The attempt to replace GM soy imports with conventional soy would lead to a 291% and 301% increase in the prices of soybeans and soybean meal, respectively, in the short-term.
5) The replacement of GM soybean imports with conventional soybeans would lead to a 49%, 54% and 85% in the cost of the ingredients used to produce fodder for cattle, pigs and poultry, respectively.
6) The increase in the price of soy would have a 11.3% impact on the production of fodder.
7) Likewise, the increase in the price of soy would have a final impact on the cost of production of eggs, poultry meat, pork and beef of 7.1%, 8.0%, 8.1% and 4.6%, respectively.
8) The possibility of replacing the protein obtained from soy as a result of the increase in the production of other crops in Spain, such as broad beans, peas, lupin beans or sunflower, is not feasible due to the large surface area required to cultivate these crops and cover the demand for protein needed to cater to the current demand of protein obtained from GM soy.

9) Such a shortage in supply of raw materials for the fodder manufacturing industry could lead to the risk of the potential dismantling of this industry in the European Union. In particular, this would affect an industry with 28,762 Spanish companies, with a turnover of €88,673M and 439,760 employees during 2013.
10) The potential shortage in supply of fodder to the livestock farming industry, due to the restriction in access to GM soy by the European industry, might not be compensated by the importation of fodder from third countries, since these are mainly suppliers of these genetically modified raw materials, so the importation of these products would be restricted.

## 10. References


Areal, FJ, Balcombe, K., Rapsomanikis, G. 2013. Testing for Bubbles in Agricultural Commodity Markets. MPRA Paper No. 48015.

Carpenter, J.E. 2011. Impact of GM crops on biodiversity. GM Crops 2, 7–23.

Carpenter, J. E. 2010. Peer-reviewed surveys indicate positive impact of commercialized crops. Nature Biotechnology 28, 319–321.

Chantreuil, F, Tabeau, A, van Leeuwen, M. 2008. Estimation of impact of EU agricultural policies on the world market prices. Paper prepared for presentation at the 107th EAAE Seminar *"Modelling of Agricultural and Rural Development Policies"*. Sevilla, Spain, January 29th -February 1st, 2008.

Devos, Y., Cougnon, M., Vergucht, S., Bulcke, R., Hewsaert, G., Steurbaut, W., Reheul, D. 2008. Environmental impact of herbicide regimes used with genetically modified herbicide-resistant maize. Transgenic Research 17, 1059–1077.

Dewar, A.M., May, M.J., Woiwod, I.P., Haylock, L.A., Champion, G.T., Garner, B.H., Sands, R.J., Qi, A., Pidgeon, J.D. 2003. A novel approach to the use of genetically modified herbicide tolerant crops for environmental benefit. Philosophical Transactions of the Royal Society B 270, 335–340.

Ervin, D. E., Carrière, Y., Cox, W. J., Fernández-Cornejo, J., Jussaume, R. A., Marra, M. C., Owen, M. D. K., Raven, P. H., Wolfenbarger, L. L., Zilberman, D. 2010. Impact of Genetically Engineered Crops on Farm Sustainability in the United States. Washington, DC: National Academies Press.

Ervin, D., Batie, S.,Welsh, R., Carpentier, C.L., Fern, J.I., Richman, N.J., Shulz,M.A. 2000. Transgenic crops: an environmental assessment. In: Policy Studies Reports.Wallace Centre for Agricultural and Environmental Policy.

Gilbert, C.L. 2010. Speculative influences on commodity prices. United Nations Conference of Trade and Development. No 197. March 2010.

Gómez-Barbero, M., Berbel, J., Rodriguez-Cerezo, E. 2008. Adoption and Performance of the First GM Crop introduced in EU Agriculture: Bt Maize in Spain. JRC Scientific and Technical Reports. Luxembourg: Office for Official Publications of the European Communities.

Guerrero, A. 1999. *Cultivos herbáceos extensivos*. Ediciones Mundi-Prensa, 6.ª edición.

Gutierrez, L. 2013. Speculative bubbles in agricultural commodity markets, Europeand Review of Agricutural Economics, 40, 217-238.

Huang, J., Hu, R., Rozelle, S., Pray, C. 2005. Insect-resistant GM rice in farmers' fields: assessing productivity and health effects in China. Science 308, 688–690.

Huang, J., Rozelle, S., Pray, C., Wang, Q. 2002. Plant biotechnology in China. Science 295, 674–677.

James, C. 2012. Global status of commercialized biotech/GM Crops: 2012. ISAAA Brief No. 41. ISAAA, Ithaca, New York.

James, C. 2014. Global status of commercialized biotech/GM Crops: 2012. ISAAA Brief No. 43. ISAAA, Ithaca, New York.

James, C. 2015. Global status of commercialized biotech/GM Crops: 2012. ISAAA Brief No. 44. ISAAA, Ithaca, New York.

Jones, P. J., Thomas, D Hazzledine, M., Rumer, C. 2014. Replacing soya in livestock feeds with UK-grown protein crops: prospects and implications. CAS Report 19. Centre for Agricultural Strategy, University of Reading, July 2014.

MAGRAMA 2014. Encuesta sobre superficies y rendimientos de cultivos. Resultados nacionales y autonómicos.

MAGRAMA 2000-2014. Anuario de Estadística. Ed. MAGRAMA, Madrid.

Madsen, K.H. y Streibig, J.C. 2004. Beneficios y riesgos del uso de cultivos resistentes a herbicidas. En Labrada, R. (Ed.): Manejo de malezas para países en desarrollo. FAO, Roma: 315-345.

Nelson, G.C., Bullock, D.S. 2003. Simulating a relative environmental effect of glyphosate-resistant soybeans. Ecological Economics 45, 189–202.

Nowicki, P., Aramyan, L., Baltussen, W., Dvortsin, L., Jongeneel, R., Pérez-Dominguez, I., van Wagenberg, C., Kalaitzandonakes, N., Kaufman, J., Miller, D., Franke, L. and Meerbeek, B. 2010. Study on the implications of asynchronous GMO approvals for EU imports of animal feed products. Final Report. LEI Wageningen and EMAC University of Missouri. Contract N 30-CE-0317175/00-74.

Popp, J., Peto, K., Magda, R., Lakner, Z. 2013. Economic impact of GM hysteria on EU feed market. American Journal of Plant Sciences, 4, 1547-1553.

Qaim, M. 2009. The economics of genetically modified crops. Annual Review of Resource Economics 1, 665–694.

Qaim, M., de Janvry, A. 2005. Bt cotton and pesticide use in Argentina: economic and environmental effects. Environment and Development Economics 10, 179–200.

Riesgo L., Areal F J. 2013. “Cultivos modificados genéticamente y sostenibilidad agraria” In: Gómez-Limón, J A and Reig Martinez, E. La sostentabilidad de la agricultura española. Cajamar Caja Rural.

Riesgo, L., Areal, F. J., Rodriguez-Cerezo, E. 2012. How can specific market demand for non-GM maize affect the profitability of BT and conventional maize? A case study for the middle Ebro Valley, Spain. Spanish Journal of Agricultural Research, 10 (4). pp. 867-876.

Riesgo, L. 2013. 15 años de cultivo de maíz Bt en España: beneficios económicos, sociales y ambientales. Ed. Fundación Antama, Madrid. Disponible en: http://fundacion-antama.org/wp-content/uploads/2013/12/Informe-15-años-de-maiz-Bt-en-España.pdf

Sanders, D.R., Irwin, S.H. 2011. New Evidence on the Impact of Index Funds in U.S. Grain Futures Markets. Canadian Journal of Agricultural Economics, 59, 519-532.

Sydorovych, O., Marra, M.C. 2007. A genetically engineered crop's impact on pesticide use: a revealed-preference index approach. Journal of Agricultural and Resource Economics. 32, 476–491.

Tabachnik, B.G., Fidell, L.S. 1996. Using Multivariate Statistics. Harper Collins, New York.

van Horne, P.L.M. 2014. Competitiveness of the EU egg sector. LEI Wageningen UR. Report LEI 2014-041.

van Horne, P.L.M., Bondt, N. 2013. Competitiveness of the EU poultry meat sector. LEI Wageningen UR. LEI Report 2013-068.

Wan, P., Huang, Y., Tabashnik, B.E., Huang, M., Wu, K. 2012. The Halo Effect: Suppression of Pink Bollworm on Non-Bt Cotton by Bt Cotton in China. PLoS ONE 7(7): e42004.

Wolfenbarger, L.L., Phifer, P.R. 2000. The ecological risks and benefits of genetically engineered plants. Science 290, 2088–2093.

USDA 2015. World Agricultural Production Circular Series WAP 3-15.