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# **Critical Evaluation of Soybean Role in Animal Production Chains Based on the Valorization of Locally Produced Feedstuff**

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Additional information is available at the end of the chapter

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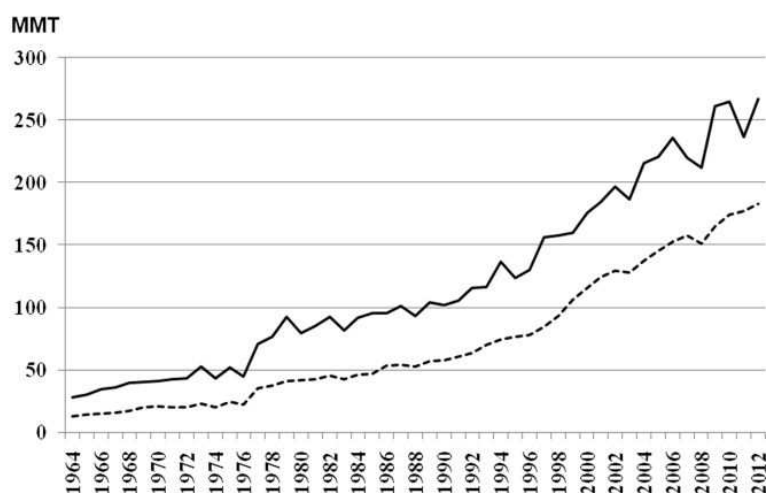
## **1. Introduction**

Commodities such as soybean and maize are respectively protein and energy concentrates that represent the basic raw materials used by the animal feeding industry and their prices influence the overall market of agricultural products. In animal feeding, soybean is mostly used as soybean meal which is a by-product of oil seed extraction industry and the availability of this raw material on the international market has led to its worldwide diffusion as the main source of protein for animal feed formulation. Soybean can also be used as raw seed due to its high fat content that makes this grain legume a valid feed to increase both protein and energy concentration of animal diets [1]. The close relationship between oil extraction industry and feed industry together with its high nutritional value for human consumption, as reported by several articles included in the present book, made soybean a perfect crop to be treated as a commodity in the world trade of raw materials.

However, despite all these positive characteristics, the diffusion of soybean and its by-products, together with the overall increased importance of the commodities trade, has triggered in agriculture several downstream effects that had deep consequences on the evolution of agricultural practices. After World War II agriculture initiated a course of progressive structural changes toward the implementation of more intense production processes due to both the need of increasing world food supply and to the progressive reduction of people employed in agriculture. The diffusion of improved varieties, fertilizers, pesticides, advanced agricultural machineries, intensive systems of animal rearing, efficient systems for the storage and transformation of agricultural products led to the abandonment of traditional cropping and animal farming systems [2]. Therefore, important agronomic practices such as crop

rotations including a cereals and legumes, cultivation of forage crops for animal feeding, a close link between animal farming and field productions useful to ensure an adequate content of organic matter in the soil were almost completely abandoned due to the diffusion of monocultures [3]. As a consequence, agricultural soil fertility decrease dramatically, as indicated by the dangerous low levels of organic matter content that at present are generally recorded in most countries that have been characterized by such an intensification of agricultural practices, and the use of chemical fertilizers became an indispensable necessity to reach economically valuable productions [4-7]. At the same time animal farming was based on the use of by-products that were available on the market to reduce the costs of production and simplify the animal production system.

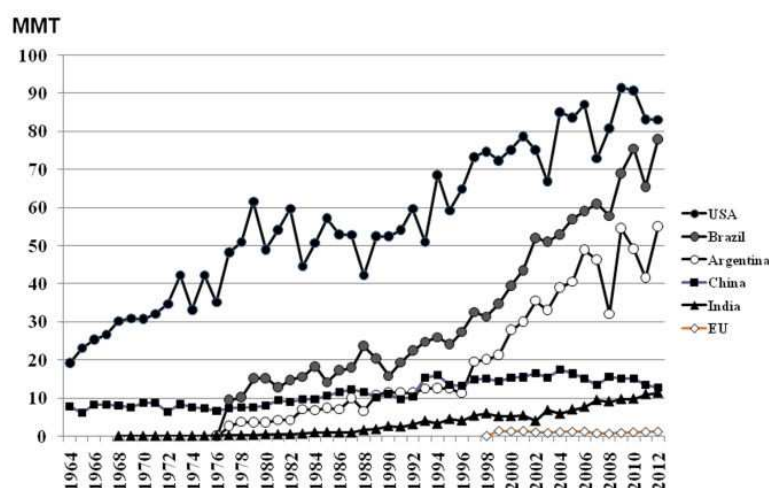
At present, globalization together with the rapid economic development actually under way in eastern countries and the world economic crisis are jeopardizing the economic feasibility of many agricultural activities, mainly in the European Union. Those farms that restructured their production processes in order to simply satisfy the demand for raw materials by the food and feed industries and by multiple retailers that manage marketing and commercialization have recently experienced the negative effects of increased costs of production followed by the low prices of agricultural products paid to the farmers. In particular, the increased costs of commodities such as soybean seed and meal that recently happened several times together with the low price of animal products paid to the farmers, mainly in the beef, pork and dairy production chains, made unprofitable the economic activities of animal farms, especially small or medium size farms.



**Figure 1.** World soybean seed (continuous line) and meal (dashed line) production.

Recently new strategies for agricultural development have emerged due to the interest of consumers toward high quality products and production chains, the increased request of

non-standardized food and the attention given to the impact of agricultural activities on the environment, human and animal health [8-10]. Therefore, an increasing number of animal farms adopted more sustainable instead of intensive production systems that were closely linked to the area of production by using locally produced animal feed and reducing their dependence from commodities. Moreover, these farms developed direct commercialization systems trying to make their business more profitable with an emphasis on the quality of both the final products and the production system.



**Figure 2.** Soybean seed production of USA, Brazil, Argentina, China, India and European Union (EU).

Aim of the present article is to critically evaluate the effects of the large diffusion of soybean on the international market concerning aspects related to the evolution of soybean trade, the effects on agricultural systems where soybean cannot be cultivated, the present dependence from soybean of intensive animal farming systems and the consequences on small or medium farms applying not-intensive animal production chains. An experience under way in the Marche Region (Central Italy) will also be illustrated as an attempt to make agricultural activity both profitable and integrated within local soil and climatic characteristics.

## 2. Soybean seed and meal trade

Data on soybean seed and meal (oil was not considered) production, import, export and prices were obtained at the Index Mundi website [11] (data source:USDA) where information on all commodities trade is available. Soybean data were usually available from 1964 to 2011 together with estimates referred to the current year 2012, even though for some countries and also for the European Union data availability covered a shorter period of time. Data

were organized in an excel data sheet and elaborated to obtain information concerning single countries involved in the soybean international trade. The total worldwide value of seed and meal production, import and export, expressed as Million Metric Tons (MMT), were then calculated by summing the data available for each country for each year. Results were summarized by graphics concerning the overall soybean trade, the characteristics of single countries significantly involved in the international market of soybean and the comparisons among different countries.

Soybean seed production progressively increased from 1964 (28,3 MMT) to 2010 (264,7 MMT) and, although followed by a slight decrement in 2011 (236,4 MMT), soybean seed USDA 2012 estimated production (referred to june 2012) is 266,8 MMT confirming the positive trend for this commodity (Figure 1).

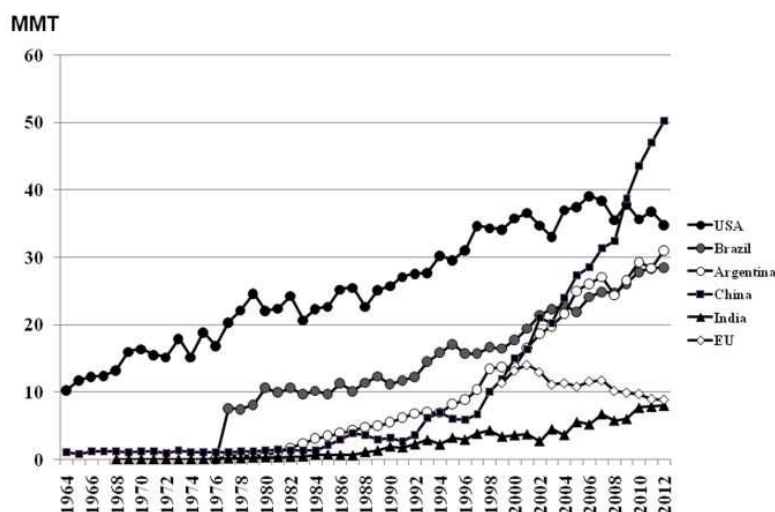
USDA data identified 42 countries characterized by an estimated soybean seed production of at least 0.001 MMT. However since 1964 more than 90% of total soybean seed production was concentrated in 5 countries (USA, Brazil, Argentina, China and India) and USA, Brazil and Argentina covered about 80% of worldwide soybean production (Figure 2).

European Union (Figure 2) produced between 0.6 MMT (year 2008) and 1,4 MMT (year 1999) of soybean seeds and in 2011 EU27 ranked twelfth with a production of 1,1 MMT (0.47% of world production). These data confirm the almost complete dependence of Europe from non-EU and mainly American countries to satisfy the needs of protein concentrates of European animal production chains.

Figure 1 also shows that the production of soybean meal had almost the same trend of world soybean seed production, with a steady increase from 1964 (13,5 MMT) to 2011 (177,4 MMT). However, the relative contribution of each country is different than what has been described for seed production. USA was the highest soybean meal producer until 2009 when it was exceeded by China that, based on the 2012 estimate, at present seems to be the world leader in soybean meal production. China showed a relatively low meal production until 1997 when it started a progressive increase in the production of this by-product of oil extraction (Figure 3).

It is interesting to compare soybean seed and meal amounts produced over time in China; soybean seed production in this country was always lower than 20 MMT, ranging from 6.14 MMT in 1995 to 17.4 MMT in 2004 (Figure 2), whereas soybean meal production was lower than 10 MMT until 1997 but increased from 10 MMT in 1998 to 46.9 MMT in 2011 with an estimated 50.2 MMT for the year 2012 (Figure 3). Starting from 1997 also Brasil and Argentina began to increase their soybean meal production reaching about 28 MMT in 2011, whereas USA, after a constant increase from 1964 to 1996, was characterized by and almost constant meal production of about 35 MMT/year in the 1997-2011 time period (Figure 3).

India, which was the fifth producer of soybean seeds, also showed a constant increase in soybean meal production from 1987 to 2011 although remaining below the 10 MMT level of meal production (Figure 3). On the contrary in the 2001-2011 time period the European Union was characterized by a negative trend of soybean meal production that decreased from 14 MMT in 2001 to less than 10 MMT after 2008 (Figure 3).



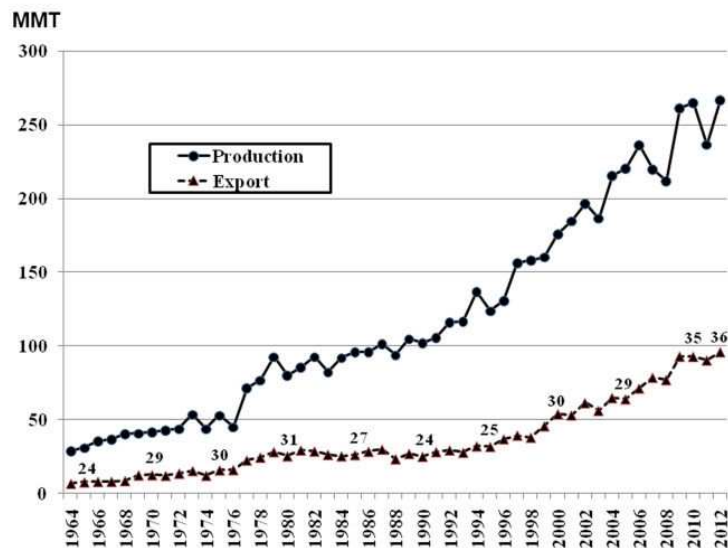
**Figure 3.** Soybean meal production of USA, Brazil, Argentina, China, India and European Union (EU).

Moreover, in the 1994-2011 time period the relative contribution to the worldwide soybean meal production of Japan decreased from 8% (1994) to 0.82% (2011) and Canada was also characterized by the same negative trend (from 3.12% in 1994 to 0.62% in 2011); this behaviour could be attributed to the low increase in meal production over time that characterized these two countries (from 1.07 to 1.45 MMT for Japan and from 0.42 to 1.10 MMT for Canada) compared to the progressive overall world increase of soybean meal production.

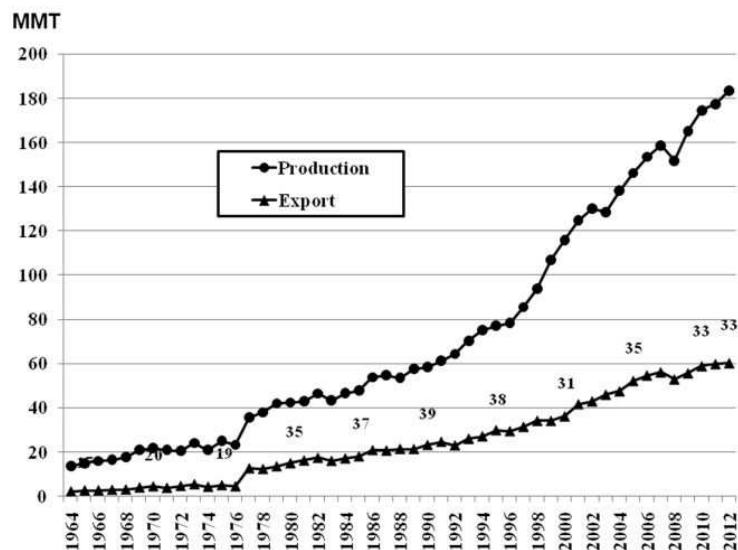
Therefore, the international scenario concerning soybean clearly shows that 3 countries (USA, Brasil and Argentina) handle almost all the world production of soybean seed, whereas China must be added to USA, Brasil and Argentina concerning the production of soybean meal. Conversely European Union has a negligible level of soybean seed production and a low level of soybean meal production as a by-product of oil extraction from imported soybean seeds. This determines that European Union animal production chains rely completely on imported soybean and this situation generates an almost total dependence of European farms from the international trade of these commodities. Data on the import/export of soybean seeds and meal also confirm that EU animal farming is suffering the effects of globalization of the markets, mostly because the dynamics of the international market of soybean is changing as a consequence of the new scenario due to the increased interest toward this commodity by several new countries.

Figure 4 and Figure 5 summarize the world scenario of soybean seed and meal trade, respectively. World seed production increase was also followed by an increase in the amount, expressed as percentage of total world production value, of overall exported seed that was about 25% until 1995, then raised to about 30% between 1996 and 2005 and finally reached the value of 35 % in 2010 with an estimated amount of 36% for year 2012 (Figure 4).





**Figure 4.** Soybean seed: comparison between world production and export; every five year export values expressed as percentage of total world production are shown (2012 data are estimated values).



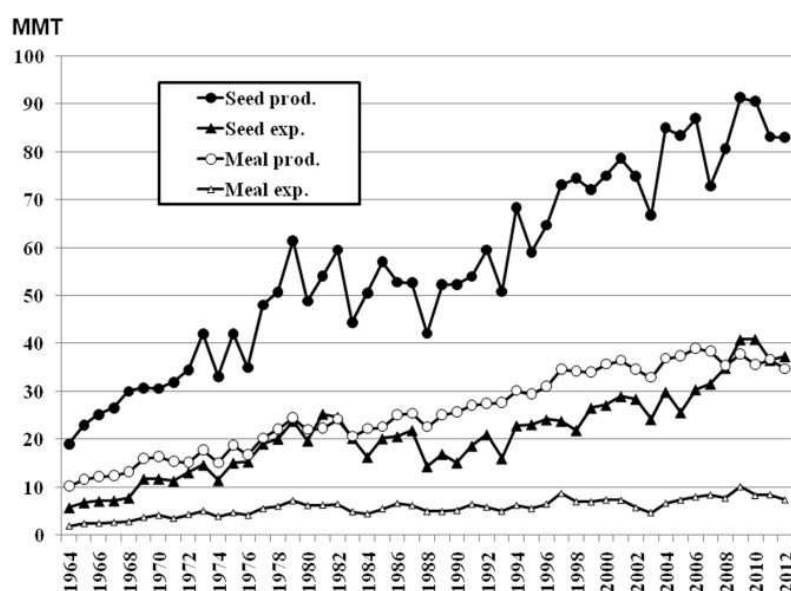
**Figure 5.** Soybean meal: comparison between world production and export; every five year export values expressed as percentage of total world production are shown (2012 data are estimated values).

A similar trend was shown by global soybean meal production. An increase from 17% to 35% in the percentage of exported meal, expressed as percentage the total world meal production, was registered in the 1965-1980 time period, a further slight increase until 38% was

observed between 1980 and 1995 and subsequently the percentage of exported meal went back to the value of 33% for year 2010, the same value estimated for year 2012 (Figure 5). Therefore, about one third of total world soybean seed and meal production is exported to countries that show a deficit in the internal production of these commodities.

The relative importance of the import/export of soybean seed and meal compared with the internal production is also shown separately for each of the 4 most important countries (USA, China, Brazil and Argentina) together with the situation characterizing the European Union (Figures 6-10).

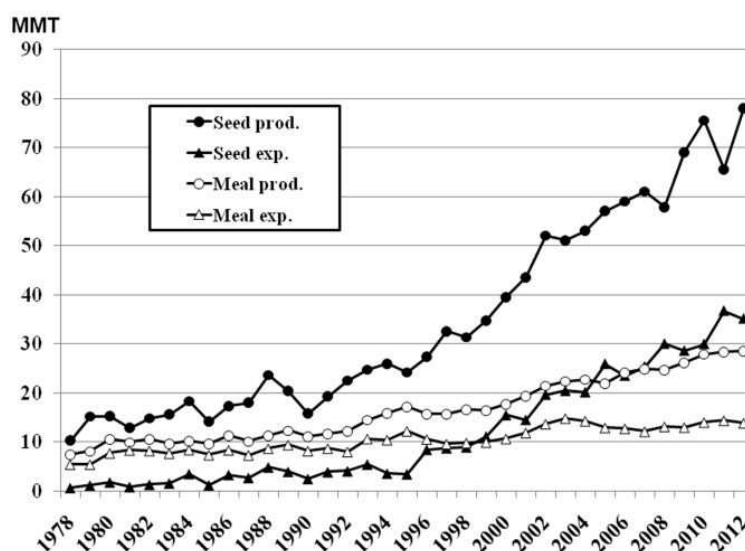
At present, USA is the highest producer of soybean seed in the world and in 2010 45% of total USA internal production was exported, this level being maintained in 2012 estimate. About 20-25% of internal USA soybean meal has always been exported (Figure 6).



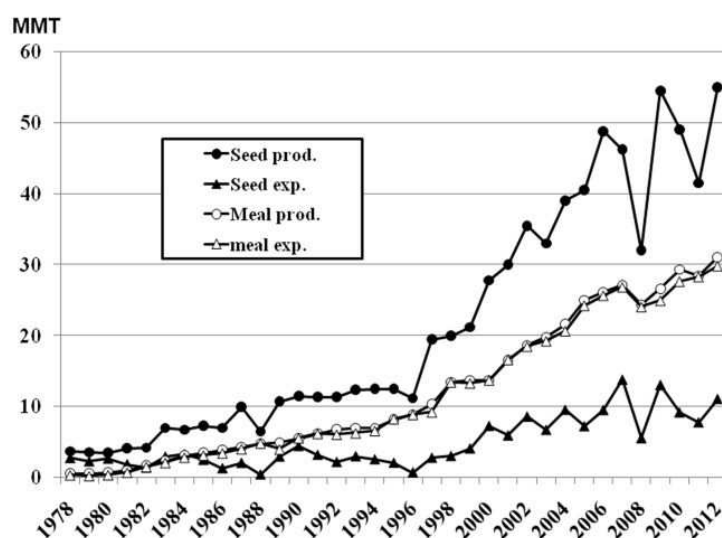
**Figure 6.** USA: Soybean seed and meal production and export; imported amounts are negligible and therefore are not shown.

Together with USA, also Brazil and Argentina (data available from 1978 to 2012) are characterized by a high amount of internal production which is exported followed by a negligible import of soybean products. In particular, Brazil is getting close to USA levels of production for both soybean seed and meal (Figures 2 and 3) and seed export, that ranged between 12 and 20% in the 1980-1995 time period, steadily increased from 30% in 1996 to 55% in 2011 with an estimate of 45% for year 2012 (Figure 7). A different trend characterized soybean meal Brazilian export that was about 76% from 1978 to 1990 and then decreased to 50% in 2011 with an estimated level of 48% for year 2012. On the whole, about 50% of both seed and meal internal Brazilian productions is exported (Figure 7).





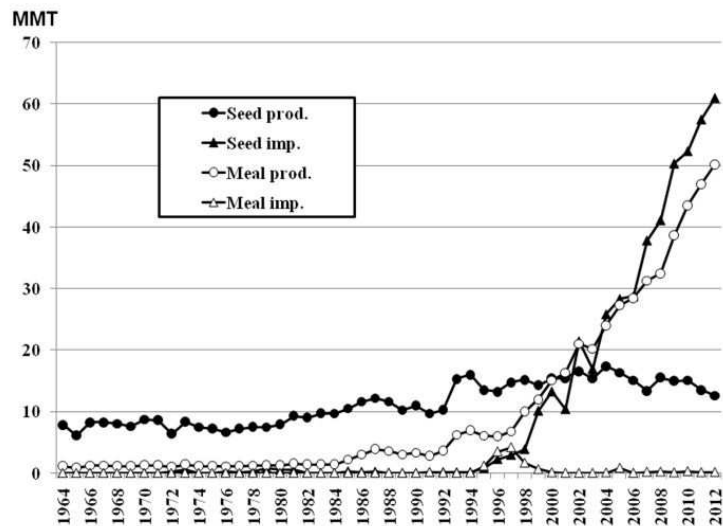
**Figure 7.** Brazil: Soybean seed and meal production and export; imported amounts are negligible and therefore are not shown.



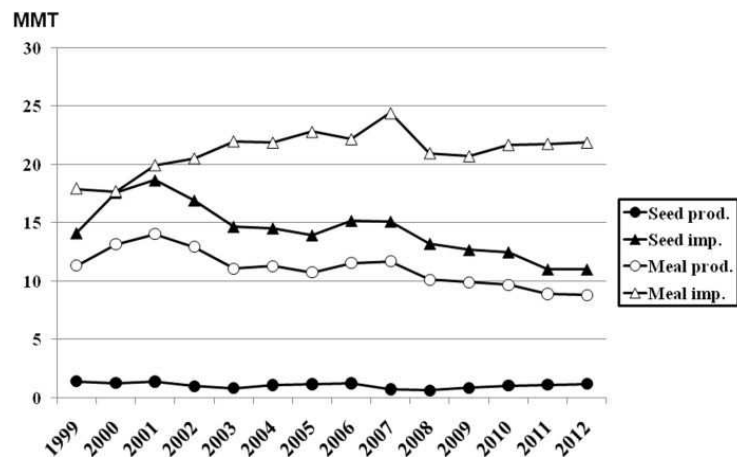
**Figure 8.** Argentina: Soybean seed and meal production and export; imported amounts are negligible and therefore are not shown.

A large amount of Argentina's seed production in 1978-1980 period was exported, but since 1981 the amount of exported seed dropped drastically to 33-55% until 1985 and thereafter it decreased even more reaching 19% in 2011 with an estimate of 20% in 2012 (Fig-

ure 8). On the other end the amount of soybean meal internally produced increased approximately four times and almost 100% of the meal was exported, as clearly shown by Figure 9. Therefore these data suggest that Argentina is essentially growing soybean to export soybean meal.



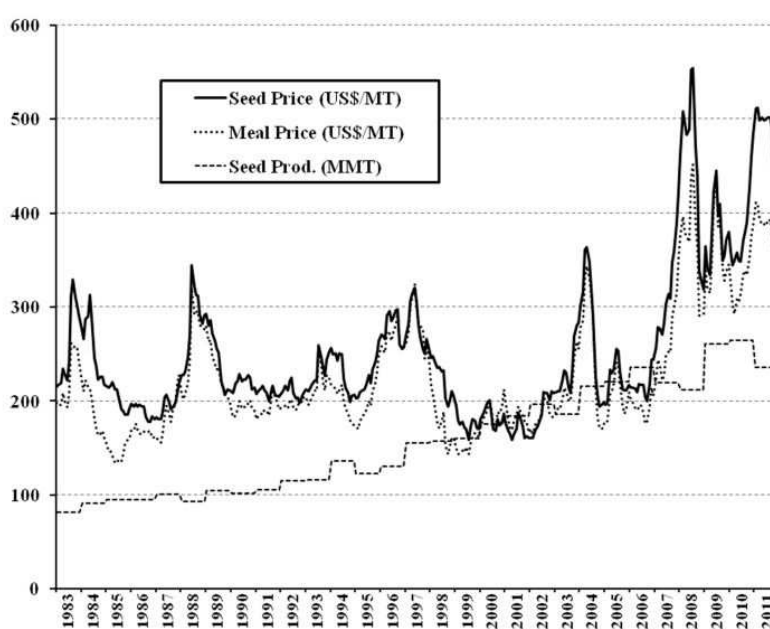
**Figure 9.** China: soybean seed and meal production and import; exported amounts are negligible and therefore are not shown.



**Figure 10.** European Union: soybean seed and meal production and import; exported amounts are negligible and therefore are not shown.

On the other hand, an important soybean importer is China (Figure 9) whose inner soybean seed production only slightly increased over time whereas this country has become the largest importer of soybean seed (61 Mt estimated for 2012). All the internal production and import of soybean seed is used for oil extraction and meal by-product production. The large amount of soybean meal produced is almost completely used within the country to support internal animal productions, since China export of meal is negligible. Due to this large volume of import China is getting a predominant role influencing the worldwide exchange of soybean products, sometimes competing with other strong importers such as the European Union (Figure 10). As a matter of fact estimated levels of 2012 EU import of soybean seed and meal are 11 and 21.9 MMT respectively, against an internal production of 1.2 and 8.8 MMT of seed and meal, respectively.

Therefore, costs of production of European animal farms strictly depended on soybean prices that are set by the international market. As shown in Figure 11 monthly price of soybean seeds and meal in the 1983-2011 time period showed a marked change in part due to the trend of world soybean production. In particular, after 2007 seed and meal prices showed a clear average increase compared to the previous years. The unpredictable variation in the price of the basic protein concentrate for animal feeding strongly influenced the incomes of European farmers since it was also related to a general increase in the prices of other commodities and production factors (fertilizers, pesticides, seed, fuels etc.) whereas the prices of animal products to the farmers did not follow the same positive trend.



**Figure 11.** Trend of soybean seed and meal prices (US\$ per Metric Ton) compared to the world total seed production (MMT) of each year.

Furthermore, the worldwide diffusion of soybean as protein feed component has almost completely replaced any other protein source for animal feeding and this happened mainly

in highly intensive farms trying to maximize animal growth rate, to simplify the management of feedstuff and to standardize meat or milk production systems. The same trend occurred for maize which is currently the most important cereal for animal production chains. Moreover, most of the soybean is produced by using new varieties obtained by genetic engineering [12] whose acceptance by European consumers is strongly debated.

On the whole, globalization of the market of animal products favoured the development of animal farms rearing large numbers of animals determining a high concentration of animals in a reduced number of farms which is typical of intensive farming systems, followed by a progressive reduction in the number of small farms that were not able to compete in such a situation of high costs of production coupled with low prices of products for the farmers.

### 3. Strategies for partial or total soybean replacement.

Therefore, even though both soybean and maize have extremely interesting nutritional characteristics as feed intended for almost all farm animals, an alternative strategy was necessary to reduce this complete dependence of European animal production chains from the market of the commodities. However, environmental and climatic conditions in most European countries hinder the cultivation of soybeans and maize because they are warm-season crops growing during the spring-summer season making irrigation a fundamental need for the success of these crops. Therefore the limited amount of lands suitable for cultivation of these crops, the high water request making irrigation a fundamental component of the production cost, the low levels of soybean grain production per hectare suggested that attention should have been addressed toward other sources of proteins to reduce dependence on imported soybean.

This is particularly true for European countries characterized by a Mediterranean climate, where rainfall is mainly concentrated during winter until late spring whereas summer is usually characterized by high temperatures coupled with very low and often irregular rainfall. Moreover, the use of water for irrigation is often very expensive and therefore, where it is available, it is devoted to other crops such as orchards and vegetables. As a consequence, in these areas agriculture is essentially based on cool-season crops that could be sown in autumn-end of winter and harvested at the end of spring or during summer. Therefore, these agricultural systems are typically based on rotations between winter cereals and grain legumes such as faba bean (*Vicia faba* var. *minor* L.), field pea (*Pisum sativum* L.), chick pea (*Cicer arietinum* L.) and white lupin (*Lupinus albus* L.). For animal feeding the most commonly used grain legume was faba bean. Recently, genetic selection of field pea new varieties stimulated the diffusion of this crop as protein source for animal feeding. Also chickpea has been proposed as a possible alternative to soybean together with sweet lupin, which is characterized by the highest protein content among the grain legumes alternative to soybean. However, since chickpea is mainly cultivated for human consumption and lupin can be cultivated only in locations with specific soil pH conditions, the main grain legume crops on which to focus attention as possible replacements of soybean are field pea and faba bean.

As a consequence, scientific research was directed to increase knowledge on cultivation, plant breeding and utilization as animal feed of these grain legumes [13-23]. Results showed that in ruminant, monogastric and avian animals at least a partial replacement of soybeans is feasible in intensive animal farming systems, whereas in low input or organic farming systems soybean can be completely replaced by grain legumes that can be grown on farm where soybean cultivation is not feasible [24]. However, despite these encouraging results, grain legume cultivation has suffered a clear reduction in Europe. This trend was related to the development of feed industry that, due to the large quantity of raw materials handled, rely mostly on commodities available on the international market and on the use of industrial protein reach by-products of oil extraction such as rapeseed meal, cottonseed meal, sunflower meal and others.

Therefore, the identification of grain legumes such as faba bean, field pea, chickpea and lupin that could at least partially replace soybean in animal feeding systems and their introduction of in crop rotation systems targeted at supplying animal production chains with locally produced protein concentrates could have several positive effects on European agricultural systems. This set of crops could guarantee, together with forage crops and pastures, the development of animal production chains that were fully integrated with local environmental characteristics. Moreover, the close link between animal farming and field productions supported the maintenance of good soil fertility and organic matter content. Finally, new strategies for the commercialization of final animal products must be undertaken for the full valorisation of the whole production chain.

#### **4. Consequences of simplified cropping systems**

The negative trend shown by grain legume diffusion was therefore a consequence of agriculture evolution toward highly specialized intensive production systems that determined the progressive gap between animal productions and field agriculture. This trend led to well-known agricultural and economical drawbacks such as lost of soil fertility, dramatic decrease of soil organic matter content, increased need of inputs (fertilizers and pesticides) to reach the highest agronomic performances, search for high productions to counterbalance the lowering prices of raw materials on both global and local markets. Moreover, a clear separation between farmers that progressively became simple producers of raw materials and industry that managed commercialization and transformation of agricultural products, over time led farmers to lose any possibility of market control. These aspects determined a deep crisis in the agricultural sectors of countries where agriculture was characterized by small or medium sized farms that lost their ability to compete on the market since they were confined to the role of simple low value raw material producers. The diffusion of monoculture, the reduction of forage crops due to the intensive feeding systems mainly based of protein and energy concentrates, the trend toward part-time agriculture, the massive use of chemicals to maximize crop production characterized agriculture for several decades after World War II. As a consequence, market of agricultural products was invaded by standardized



products that replaced most of the typical and local productions that previously characterized agricultural systems strictly integrated with the areas of production.

Recently, the need for a more environmental friendly agriculture together with the increasing request by the consumers of high quality products, stimulated farmers to recapture the market of agricultural products [25]. These farms progressively abandoned standardized and intensive agriculture and dedicated to animal and crop productions following the vocation of their own local region.

As far as animal production chains are concerned, the reconstitution of local production systems led to the valorisation of animal feeding systems based on locally produced raw materials, both forages and protein (grain legumes) or energy (cereals) concentrates. This allowed these farms to reintroduce rational crop rotations, that were abandoned due to the diffusion of monocultures, by alternately cultivating those cereals and legumes that could also be intended for animal feeding. Most of these farms started to commercialize by their own the products of their farms by an action aimed at informing the consumers about all aspects of their production system, receiving economical and professional satisfactions.

This approach led to partly or completely replace soybean in animal diets, to reintroduce forage crops both in field crop rotations and in animal feeding systems, to develop less intensive animal farming systems, to stimulate creation of local networks among farmers which could represent a further stimulus for local farms to reintroduce grain legumes and forage crops for animal feeding by making agreements with local animal farms that would withdraw their legume products.

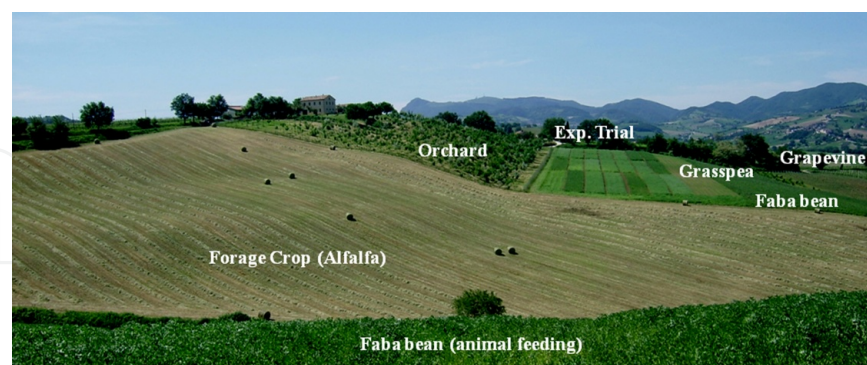
## **5. Experiences on soybean replacement carried out in the Marche Region (Central Italy)**

On the feasibility of local animal production chains a research, funded by the Marche Region (Central Italy), has been carried out by our research group since year 2000 to evaluate the technical and economical possibilities of soybean replacement with grain legumes such as *faba* bean and field pea. At the same time research evaluated the possibility of a total or partial replacement of maize with barley or sorghum grain, since both these crops are valuable energy crops for areas characterized by high temperatures and low rainfall during summer, since barley is a cool season cereal whereas sorghum is a warm season but drought resistant cereal crop.

The first objective of the project was to test the agronomic feasibility of both faba bean and field pea in different areas of the Marche Region [26-27]. Very favourable lands, where these crops have been evaluated in optimal agronomic conditions, and more marginal fields were included in field trials. Moreover, several farms including both conventional and organic farms were involved as partners of the project to carry out "on farm" field trials based on large plots that were managed by the farmers themselves. The "on farm" approach allowed the evaluation of the real potential of these crops in the areas under exami-



nation, that were mainly located in the inner part of the Marche region where irrigation is not feasible (Figure 12).



**Figure 12.** Field experimental trial including faba bean and field pea carried out in typical agricultural landscape of inner areas of the Marche Region (Province of Ancona).

Results showed that both faba beans and field pea could be effectively reintroduced in crop rotations with winter cereals such as wheat and barley, reconstituting a correct alternation between nitrogen fixing legumes and cereals. However, the grain productions obviously varied based on the environmental and soil conditions and the seasonal climatic conditions that varied from year to year. This experience allowed the creation of a useful data set indicating that faba beans showed, on the average, a range between 1.0 and 3.5 tons/hectare of grain, the lowest productions being obtained when very dry growing seasons occurred with extremely low values of rainfall during end of winter and spring. Farmers know very well these characteristics of faba beans since this crop has been traditionally used across the whole region mainly as protein grain for beef cattle of the Marchigiana breed. However, plant breeding efforts are requested to stabilize grain production in the variable environmental conditions characterizing the inner areas of Central Italy.

Field pea was characterized by a higher average seed production than faba beans, showing a range between 1.5 and 4.5 tons/hectare. For this crop low production can be due to environmental adverse conditions but also grain loss due to seed shattering during harvesting is a primary cause of production losses mainly when the crop is grown on soils with an irregular surface that makes threshing difficult.

To compare faba bean and field pea with soybean, few farms where irrigation was feasible were asked to try cultivation of soybean. The results showed an average seed production between 2.5 and 3 tons/hectare, similar to a good faba bean or field pea harvest, but costs of irrigation made this crop unprofitable. Moreover, chemical weed control was necessary in order to obtain acceptable seed production because watering also favoured the development of weeds. Herbicides are used also to protect faba beans and field pea against weed competition. However, our field trials carried out in organic farms showed that multi-year rotations including forage crops such as alfalfa, highly competitive cereals against weeds such as barley or wheat, and a higher crop density (number of plants/m<sup>2</sup>) than conventional cultivation can avoid the use of herbicides on crops such as faba beans and field pea.

Results of the field trials showed that these grain legumes can be effectively produced in inner areas of the Marche Region where soybean cannot be cultivated and animal farming is traditionally an economic source of income for local farmers. After gathering information on the agronomic feasibility, research has been addressed to verify the possibility of total or partial substitution of soybean with faba beans and/or field pea in beef cattle, dairy cattle and swine feeding systems. Therefore, feeding trials were conducted in one large dairy farm, located in the Province of Ancona, 4 organic farms rearing beef cattle of the Marchigiana breed and located in the Provinces of Macerata and Fermo, one conventional farm located in the Province of Pesaro-Urbino, and one conventional small familiar swine farm, located in the Province of Fermo, rearing pigs using a non-intensive farming system.

Concerning the dairy sector, our experimental trials were carried out while farmers were experiencing the continuous fluctuation of the prices of raw materials, mainly commodities such as soybean meal and corn grain, coupled with the crisis of the dairy sector across all Europe that determined low milk prices despite the increasing costs of production. Therefore, we were able to evaluate both the potential and the limits of soybean and corn partial replacement in a very critical agricultural sector such as dairy farming. Due to the peculiarities of dairy production, based on the animal physiology and on the nutritional characteristics of the raw materials under examination, soybean meal cannot be totally replaced by faba bean and field pea. Based on the results of the “on farm” feeding trial carried out at this dairy farm about 50% of soybean meal present in the ration was replaced by faba bean and field pea. To understand the potential effect of this partial substitution on the local agricultural system it can be considered that the farm was initially using 3kg/cow of soybean meal. Therefore, 1.5 kg of soybean meal were substituted by about 2 kg/cow of faba bean/field pea mix, considering that also part of the corn grain was also partially replaced by these grain legumes due to their starch content. Having the farm an average of 450 lactating cows per day, daily feeding requested about 9 tons/day of faba bean and field pea, which was about 330 tons/year. Based on the results of the field trials, assuming an average field production of 2.5 tons/hectare (2 tons/ha for faba beans and 3 tons/ha for field pea) it can be estimated that this farm could support about 130 hectares cultivated with grain legumes for animal feeding. Assuming a multi-rotation such as wheat-grain legume-barley- 3 years of alfalfa we can roughly estimate that partial substitution of soybean in this case could support an overall agricultural system covering about 790 hectares. Moreover, the presence of a 3 years forage crop such as alfalfa would reduce drastically the use of pesticides and fertilizers and also would increase nitrogen fixation and soil organic matter content, the introduction of organic farming practices to manage cereal and grain legume crops would avoid or at least reduce the use of chemicals and in particular of herbicides also in conventional farms, the milk production would be closely linked to the area of production. However, to make this system working it is necessary to make it economically profitable for the farm. When soybean meal prices increased the use of grain legumes produced by local farms helped the dairy farm to compensate for the increased costs of production. Despite these encouraging results the crisis of the dairy sector is hampering the implementation of this integrated production system that is based on close relationships between the dairy farm and farmers producing raw materials used as animal feed. The identification of different commercialization systems able to fully

valorise the quality of the overall production chains is becoming a fundamental step in order to counteract the continuous decrease of milk price on the national and international market.

Beef cattle field trials were carried out at four organic farms located in the inner areas of Provinces of Macerata and Fermo. Differently from the experience previously described in the dairy sector, the small size of these farms, the high quality of both final products and production system and a different approach to the product valorisation based on the direct sales of meat by the producers themselves, allowed research results to be transferred to the final step of the production chain: the product marketing and commercialization.

Feeding trials on organic beef cattle showed that for not intensive production systems soybean can be totally replaced by faba beans and field pea. Moreover, these farms are characterized by self-producing almost all the forage and a high amount of protein (grain legumes) and energy (mainly barley) needed for animal feeding. It is relatively simple for these farms to make arrangements with neighbouring farmers to secure themselves the supply of the raw materials they are not able to self produce. This production system is extremely interesting because, as shown in Figure 13, it is based on rational agronomic crop rotations maintaining both a high level of crop diversification together with a low if not positive environmental impact due to the organic farming practices. The lower animal daily growth rate characterizing organic or non-intensive animal farming (1-1.2 kg/day), compared to growth rate of intensive systems (higher than 1.6 kg/day), is also an aspect of the production system which is valorised in the final product.



**Figure 13.** Organic animal farm located at Monte San Martino (Province of Macerata) where both experimental field and feeding trials were carried out.

Aim of the research project was also to verify the technical and economic feasibility of GM-free production chains, that is production systems that do not include genetically modified (GM) feed in the feeding system. Among the commodities, soybean show the highest amount of worldwide production obtained from GM varieties, mainly cultivated in USA or South America [12]. Therefore, since almost soybean seed or meal used in the European Un-



ion is imported by American countries, the risk of GM soybean contamination is very high. This is confirmed by the introduction of a threshold of 0.9% technically unavoidable contamination also in organic feedstuff. Therefore, our results demonstrated that also organic farming systems could avoid GM contamination whenever a strict control of the raw material production or origin is made directly from the farmers. Feed composition therefore becomes an index of the raw materials used in the production chains and can be used as further information for the consumers to valorise the value of the final product. For these reason a DNA method has been developed as further result of the project aimed at the identification of the presence of faba beans and/or field pea within feed samples [28]. This could be a simple and not expensive approach to certify the use of local raw materials as feedstuff together with the absence of soybean from the ration. Moreover, an attempt to increase consumers' information about the characteristics of GM *free* organic production has been started as part of dissemination of the project activities and this increased the number of consumers interested in purchasing GM *free* products. On the whole, results on organic beef cattle showed that GM *free* production chains based on feeding systems that rely on locally produced raw materials can be an efficient alternative to intensive production chains. This approach could also be useful to maintain or increase economically effective agricultural systems in inner areas of Central Italy by reducing the dependence from the international market of commodities.

Encouraging results have also been obtained concerning the swine production chain. The farm where feeding trials were carried out had the possibility of rearing pigs both indoor and outdoor (open air). Therefore a feeding trial was conducted to compare one conventional feed (Control) based on the use of soybean meal and corn with an experimental feed where soybean meal was replaced completely by faba beans and field pea and corn was partially replaced with barley. Both feeds were formulated respecting the differences requested between the growth and the finishing phases. No differences in animal growth rate (600 g/day) were detected between the two feeds (Control vs Experimental). At the same time a group of pigs was reared outdoor and fed with the experimental feed. Average daily growth rate was slightly lower than observed in the indoor trial. The same experimental feed was subsequently tested in one organic and one conventional farm and results confirmed that regular growth rates can be obtained when soybean is not included in the feed, with slightly higher average daily gains obtained in the conventional farm (750 g/day). Therefore, non intensive swine production chains could represent another animal farming system that could stimulate the development of production systems linked to the production area, the networking among local farms concerning the exchange of raw materials for animal feeding, the reintroduction of rational not intensive agricultural systems. Commercialization of the final products is again fundamental to guarantee profitability for all the actors of the production chain and for this purpose direct selling is showing to be an effective marketing strategy to reach this objective.

## 6. Conclusions

The main objective of this paper was to stimulate a critical evaluation of soybean impact on agricultural systems where soybean cannot be cultivated. Notwithstanding soybean positive nutritional characteristics, this commodity may not be the only solution for animal production chains for those countries that may suffer from a complete dependence on import of raw materials.

Field and feeding trials carried “on farm” furnished information on the feasibility of local animal production chains using feeding systems based on locally produced raw materials that could partially or completely replace soybean. This possibility would be a stimulus to recreate networks among local farmers in order to develop local production chains that could restore an economically feasible agricultural systems to farms that are unable to compete on the global market. This also represents an attempt to reintroduce sustainable agricultural systems characterized by a reduced use of chemicals and pesticides due to the cultivation of low input cereals and legumes in rationale crop rotations.

Moreover, the interest toward research results on feedstuff that do not include soybean is also related to the risk of GM contamination due to this commodity. GM free animal production chains are strongly exposed to GM contamination when soybean is included as the main protein source in the feed. The decision to include the 0,9% threshold also for organic farming production chains underlines the real risk of GM contamination and the difficulties to create GM free production chains when the feed is based on the use of the same raw materials characterizing GM animal products.

Our results however showed that for large animal farms, that carryout intensive production systems, it is more difficult than for small farms, characterized by not intensive production chains, to manage soybean replacement. This aspect confirms the almost complete dependence from imported commodities that has been reached in the time by agricultural production sectors aimed at the mass production of large amounts of standardized products. The large volume of raw materials requested followed by the low internal availability of feedstuff that can be used as an alternative to soybean exposes these farms to the risks of international market variations both in the availability and in the price of this commodity.

On the other hand, the implementation of animal production chains based on the use of locally produced feedstuff is a valid approach for small farms producing high quality products using not intensive animal farming systems. These farms can in this way gain a market space for products that can be an alternative to standardized products and at the same time activate agricultural systems well integrated with local environmental features, that make less use of intensive production techniques, reduce the use of fertilizers and pesticides, restore soil fertility. However, new marketing strategies are necessary to make consumers aware of the importance of the overall characteristics of local production chains in defining the quality of a final product and to ensure at the same time a profitable price for the producers.

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