

Soybeans *Glycine max*

Production

Area Under Cultivation	74.1 Million ha
Global Production	161.2 Million MT
Average Productivity	2,176 kg/ha
Producer Price	\$195 per MT
Producer Production Value	\$31,477 million

International Trade

Share of World Production	57%
Exports	91.6 million MT
Average Price	\$204 per MT
Value	\$18,728 million

Principal Producing Countries/Blocs (by weight)

United States, Brazil, Argentina, China
India, Paraguay, Canada, Bolivia, Indonesia

Principal Exporting Countries/Blocs

United States, Brazil, Argentina,
Paraguay, Netherlands, Canada,
Bolivia

Principal Importing Countries/Blocs

China, European Union, Japan, Mexico,
South Korea, Thailand, Indonesia

Major Environmental Impacts

Conversion of natural habitat
Soil erosion and degradation
Agrochemical use
Genetically modified seeds

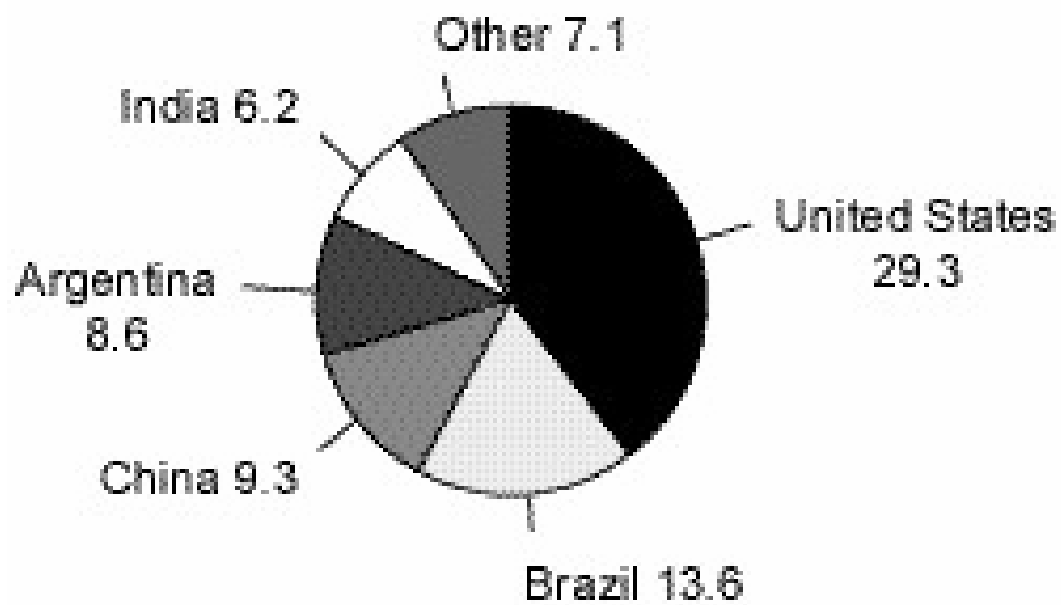
Potential to Improve

Good
BMPs are being identified and current prices can
cover cost of adoption
Conservation tillage and zoning can reduce main
impacts
Possible to produce more on less land with fewer
inputs

Source: FAO 2002. All data for 2000.

Soy

Area in Production (MMha)



Chapter 8

Soybeans

Overview

Soybeans were first cultivated in China perhaps as many as 6,000 years ago, making soybeans one of the first domesticated food crops. During the Zhou Dynasty (eleventh century to 256 B.C.) and the Qin Dynasty (221 to 206 B.C.) soybeans became one of the main food crops in the Yellow River valley. By the Ming Dynasty (1368 to 1644 A.D.), soybeans were grown throughout the country.

The soybean is the “king of beans.” Dry, it contains 38 percent protein—twice as much as pork, three times more than egg, and twelve times more than milk. Furthermore, the protein in soybean has a more complete range of essential amino acids than most other foods. In addition, the dry seed contains 18.4 percent unsaturated fat. Many soybean products (e.g. miso, soy sauce, tempeh, and bean curd) originated in China. For example, bean curd (tofu) was invented in the Han dynasty (206 B.C. to 220 A.D.). The technology then spread to Japan around the year 700 A.D. (Tengnäs and Nilsson 2002).

Soybeans, along with silk, tea, and porcelain, were one of the earliest exports from China. China displayed soybeans at the Vienna Fair in 1873, and the product then became better known to the outside world. At the beginning of the twentieth century, China began to export soybeans. Production in China reached 11.3 million metric tons in 1936 and accounted for 80 to 90 percent of the world market (Tengnäs and Nilsson 2002).

Initially, soybeans were used primarily for human consumption and still are in parts of Asia. In the United States, though, soybeans have not been grown for direct human consumption until recently. Rather, they are grown primarily to provide cheap, high-protein animal feed. In particular, they were developed as a substitute for fish meal that left no fishy taste. Confined poultry and pork operations developed as a result of the availability of a relatively cheap, nutritious feed source for animals. Soybean oil, which is now the most-consumed oil in the world, was first a byproduct from the crushing of soybeans for meal. After World War II soybean production was introduced in many parts of the United States. By the 1960s the cultivation of soybeans had expanded rapidly, displacing many other crops and becoming the main rotational crop in association with corn. Soybean production was encouraged by agricultural extension agents because the crop is a legume and fixes nitrogen in the soil for uptake by subsequent crops of corn.

Through the development of different seed varieties, improved nutrient input packages, and mechanized planting and cultivation, a monocrop soybean production system was developed in the United States. This monocrop technology has been adapted to local conditions and spread throughout the United States and the world, including some of the world’s most biodiverse ecoregions. Of particular concern from an environmental point of view is the rapid expansion of soybean cultivation into the natural habitat of the

Brazilian cerrado (a relatively flat, mixed woodland and savanna area of central Brazil). Soybean production has spread even more rapidly throughout Brazil than it did in the United States.

Producing Countries

The Food and Agriculture Organization of the United Nations (FAO) lists 82 countries that produce soybeans. In 2000 there were 74.1 million hectares of soybean production globally. The United States led all producers with more than 29.3 million hectares. Brazil was second with nearly 13.6 million hectares in production. China was third with more than 9.3 million hectares, Argentina was fourth with 8.6 million hectares, and India was fifth with nearly 6.2 million hectares planted to soybeans. These five countries accounted for 90 percent of land planted to soybeans globally and 92.1 percent of total production (FAO 2002).

The main producing countries by weight are the United States (75.1 million metric tons), Brazil (32.7 million metric tons), Argentina (20.2 million metric tons) and China (15.4 million metric tons). In 2000 these four countries accounted for 81 percent of global production. In addition India, Paraguay, Canada, Bolivia, and Indonesia are significant producers. In the past, much of Paraguay's reported production was probably trucked across the border from Brazil to avoid taxes. However, now soybean production in eastern Paraguay is increasing dramatically at the expense of the Atlantic coastal forest in the region.

While Paraguay's overall production is considerably less than that of the largest producers, soybeans are planted on more than 25 percent of all agricultural land in the country. The following countries devote from 10 to 25 percent of all cultivated land to soybeans: Argentina, Brazil, Indonesia, North Korea, and the United States.

Of the largest soybean producers, the United States has the highest average yields, 2,561 kilograms per hectare, though some of the smaller producers achieve even better results. Brazil produces on average 2,400 kilograms per hectare and Argentina 2,340 kilograms per hectare. China's yields are only 1,656 kilograms per hectare. India is far behind with average yields of only 986 kilograms per hectare.

Switzerland reports the highest yields in the world with 4,000 kilograms per hectare. Italy reports the second highest yields, producing more than 3,576 kilograms per hectare. Ethiopia reports yields of 3,571 kilograms per hectare. Though total production is low, the average yields reported in these three countries exceed those of all other countries by a wide margin. If the statistics are accurate, further investigation might indicate why their systems are so much more productive than in other countries (FAO 2002).

Yields have increased considerably through genetic improvements and the use of pesticides and fertilizers. For example, in Brazil production in 1940–41 was 651 kilograms per hectare per year. By 2000–01 average yields had increased to 2,720

kilograms per hectare (Tengnäs and Nilsson 2002) or some 4 times higher as reported by the FAO in 2000 (FAO 2002). Two new varieties in Brazil are expected to increase yields to 3 to 4 metric tons per hectare per year (Tengnäs and Nilsson 2002).

Soybean exports can be significant sources of income for both large and small countries. Oil seed cake from soybeans is Argentina's leading export; Paraguay's leading export is oil seed cake and its second largest export is soy-based animal feed. Soybeans are the second largest export for Cambodia, and soybean cake is the third largest export for Brazil (ITC 2002; UNCTAD 1994).

The area of land in soybean production has grown at a rate of 3.2 percent per year in recent years even though prices have been declining. From 1995–2000 Paraguay led all countries in percent growth of area planted in soybeans with 62 percent, followed by Brazil (47 percent) and the United States (33 percent). Soybeans now occupy the largest area of any agricultural crop in Brazil with 21 percent of total cultivated area. The area planted to soybeans in Brazil has increased by 2.3 million hectares since 1995 for an average increase of 320,000 hectares per year. To put this another way, since 1961 the area under soybean production in Brazil has increased 57 times while production volume has increased 138 times (World Bank 2002).

Consuming Countries

Most soybeans, whether for human or animal consumption, are processed before use. Even with some direct human consumption in Asia and elsewhere, only a small percentage of soybean solids are consumed directly by people. In the United States less than 1 percent of soybean solids produced are consumed by humans (Schnittker 1997). On the other hand, most soybean oil is used to make a wide variety of food products that are consumed directly by humans. About 2.5 percent of oil production is used in paint, soap, plasters, and other inedible products.

Much consumption of soybeans occurs in the countries of production. However exports in 2000 accounted for 57 percent of total production, and exports have grown by 45 percent since 1995. The European Union and China account for 59 percent of the international trade in soybeans. However, while the European Union imports have remained stable for the past six years, the imports in China have increased 342 percent during that period (World Bank 2002).

Production Systems

In most countries, soybeans are planted in rows. In the United States the rows are spaced about 1 meter (3.5 feet) apart, and beans are planted about every 5 centimeters (2 inches) in the row. In Brazil the rows are planted closer together. Like most other annual crops, virtually everything about soybean cultivation is mechanized, from the preparation of the soil to planting, cultivation, application of chemicals, and harvesting. Cultivation

practices such as no-till, conservation tillage or direct planting all refer to ways to reduce or eliminate soil preparation. As a result they leave far more organic matter on the surface, reduce total machinery used, and reduce overall costs of production.

Efforts have been made to “drill” soybeans by planting them in rows only a few inches apart, a technique similar to that used for wheat. It was thought that this planting technique would reduce soil erosion, but that did not prove to be the case. In addition, this planting technique requires considerably more seed while reducing production per plant. It does not make sense financially. Likewise, there have been attempts to plant two crops per year in some areas, but even in the tropics the combined yields of the two quicker-maturing crops do not generally equal that from a longer-growing single crop.

Varieties differ somewhat regarding the time required for maturation. In the United States, where most production areas have a shorter growing season, most soybeans mature in about 95 to 100 days. Plants grow about 1 meter tall and slightly less across. In Brazil, the varieties planted mature in 115 to 145 days, and the longer growing season produces larger plants. The beans come from dozens of pods attached to the main stem or significant branches of the plant. Each pod contains three to four soybeans. Production in Brazil’s Cerrado region, with its longer growing season, is higher (by some 20 percent) than in the United States because the larger plants produce more significant branches that flower and set seeds.

Agrochemical use in soybean production is relatively low compared to other annual crops. Cotton production, for example, uses eight times the applications of chemicals per acre. In the United States soybeans were grown on 20 percent of the agricultural land but accounted for only 12 percent of total pesticide use in 1995, down from a peak of 24 percent of total pesticide use in 1982. Herbicides make up a large proportion of the chemicals used. A detailed report on herbicide use in the seven main soybean-producing states in the United States indicates that nearly all soybeans planted in the United States are treated with herbicides at some point. Most of these herbicides are applied directly to surface soil rather than by airplanes, as sprays, or in irrigation water (Schnittker 1997).

In Brazil, pesticides, including the herbicide glyphosate (Roundup), are used on soybeans as well. Most of the pesticides used in Brazil are similar to those in the United States. In the southern part of the country the genetically modified variety bred to withstand herbicides (commonly called the “Roundup Ready” soybean) is estimated to be grown on 60 percent of all land in soybean production—even though it is illegal (Leibold et al. 2001a). In the northern part of the country, glyphosate and similar herbicides are used in no-till operations, and producers spend from U.S.\$40 to U.S.\$50 per hectare for herbicides (Leibold et al. 2001a; 2001b).

Herbicides are not the only pesticides used. Some insects and diseases are particularly problematic in Brazil because of the year-round warm climate. Planting in narrow rows, as is common in Brazil, accentuates these problems. About 90 percent of soybean seed is treated with fungicide to prevent mildew and mold. Other diseases include stem canker and sudden death syndrome, which is associated with no-till practices and high rainfall. Soybean cyst nematodes were discovered in Brazil in 1992 and some 2 million hectares

are now infected. Insects also cause problems. Some producers are using biological controls for some insects; others are spraying several times during the growing season, which adds substantially to the cost of production (Leibold et al. 2001a; 2001b).

Harvesting occurs once per year. Soybeans are harvested and threshed mostly by combines that move through the fields, cutting the stalks and separating the grain from the pod and the rest of the plant. After being combined the beans are transferred to waiting trucks and transported to on-farm bins or directly to grain-storage depots. The depots are usually connected by rail or barge lines to more distant warehouses, processors, and/or markets.

Soils and weather during the growing season and any post-harvest storage or handling problems on farm after harvest largely determine the grade, which in turn determines the price that a producer gets for the beans. When soybeans are sold, the farmer receives a receipt for the weight of the beans. This receipt also records the average moisture content (to more accurately calculate dry-weight volume) and the quality of the beans (e.g. presence of weed seed and other vegetable matter, dirt, and stones to determine if the price should be reduced due to contamination by foreign matter). At the commercial grain elevator, soybeans are sorted according to quality until they can be dried or cleaned to the same standards.

In the United States some 380,000 farmers produce soybeans, and this crop accounts for about 20 percent of all cropland. The farm-gate value of soybeans in the United States alone is \$15 to \$16 billion, or about 16 percent of farm receipts from all crops. As the soybean is processed and moves through the system its worth increases to several times that value. In the United States, the average amount of land planted to soybeans on a farm is about 100 hectares, while in the Brazilian cerrado the average size is 1,000 hectares (Stringfellow 2000). On average, land in the cerrado can be purchased and put into production for about U.S.\$625 per hectare (McVey et al. 2000a). The purchase price in Iowa is several times this. In addition, Brazil has about 94 million hectares (234 million acres) of land in the cerrado alone that would be suitable for production of crops like soybeans, while the United States has almost all of its suitable land in production at this time (McVey et al. 2000a).

Brazilian soybean yields in the areas of expansion are superior to those in the United States, 3.03 metric tons per hectare (45 bushels per acre) compared to 2.56 metric tons per hectare (38 bushels per acre) in the United States. Production in Brazil could be increased even more by reducing harvest losses, retiring old equipment, training harvesters, and changing harvest conditions. In addition to longer growing seasons that produce larger plants, rainfall in Brazil is more predictable and continues well into the growing season. Inputs are cheaper so producers use more. Another major factor has been the development of hybrids that have greater resistance to diseases and insects, and more hybrids are in development at this time. The government is developing training programs for equipment operators. All of these factors will help Brazil to achieve the overall goal of increasing production by 680 kilograms per hectare (10 bushels per acre) within ten years (Leibold et al. 2001c).

The total nonland cost of production per hectare is higher in the state of Mato Grosso, Brazil (U.S.\$1,040) than in Iowa (U.S.\$870). However, the relevant comparison is cost per metric ton or bushel. In this case, Brazil has an advantage because productivity is higher in Mato Grosso. Brazil's greatest competitive advantage, however, is its cost of land. The land cost for soybeans in Iowa is \$87 per metric ton (\$2.38 per bushel) higher than for Mato Grosso. Total soybean production costs including land are \$78 per metric ton (\$2.13 per bushel or 61 percent) higher in Iowa than in Brazil (Baumel et al. 2000). Given that the current average price for exported soybeans is \$204 per metric ton, this difference in cost is very significant. As the price of soybeans declines, this discrepancy will challenge Iowa producers' ability to remain competitive and financially viable.

In the Brazilian cerrado crop rotation is common. Rice or pasture is usually planted first to condition the land and build up levels of organic matter in the soil for subsequent soybean production. After soybean rotations have been started, cotton and corn are the preferred rotation crops during the three-year cycle. As a part of this production cycle, area in cotton has increased 600 percent in the cerrado (Leibold et al. 2001c). Even longer-term rotations are also becoming common. For example, many cattle ranchers lease their land (payment is based on shares of production so that both risk and gain are shared) to soybean producers for a period of up to five years to rebuild the soil and then return the land to pasture for up to 7 years.

Transportation costs, too, vary between the United States and Brazil. Producers in the United States, for example, have a clear advantage to ship to Asian markets and a smaller advantage to ship to Europe. To date, transportation infrastructure in the United States has benefited from larger public investments and subsidies than those in Brazil.

Soybeans are valuable. Even so, in the United States subsidy payments to guarantee minimum prices for soybeans are an important reason that so many producers continue to plant them on such a large scale even in the face of declining prices. The expansion of soybean production in other parts of the world is also linked to government support. Subsidies for credit, inputs, technology, and infrastructure have been important for the expansion of soybeans in such countries as Brazil. In 1996 there were only 1,800 hectares of soybeans in Rondônia in the western Amazon, but the area planted increased to 14,000 in 1999. In the eastern Amazon in the state of Maranhão the area planted to soybeans increased from 89,100 to 140,000 between 1996 and 1999 (Fearnside 2000).

Tremendous subsidies have been invested in and are planned, too, for Brazilian infrastructure that is intended primarily for soybean production. This will stimulate habitat conversion. Infrastructure projects that are planned or underway include the Madeira Waterway, the Itacoatiara soybean terminal, part of the North-South railway, and the BR-333 highway linking southern Maranhão and Minas Gerais. Projects that have been developed on paper include four canals/waterways, three railways, and two major roads. Other projects are being considered.

Genetically Modified Soybeans

In recent years, genetically modified soybeans have been developed and widely adopted by producers in the United States and, to a lesser extent, in Argentina, Canada, China, and even Brazil. Because transgenic soybeans raise important issues both from the point of view of production as well as markets, it is important to highlight some considerations at this point. Herbicide-tolerant (“Roundup-Ready”) soybeans, developed and sold exclusively by Monsanto, became available only in the mid-1990s. Today they account for more than half of all soybeans planted in the United States. Brazil is engaging in a debate regarding whether transgenic crops (including soybeans) will be legal even though some reports suggest that more than half of the soybeans planted in the south of Brazil are already genetically modified varieties (Leibold et al. 2001a).

Genetically modified soybeans offer considerable appeal for producers. With transgenic varieties of soybean, producers report that they use fewer chemical inputs, especially herbicides because they can time the use better. They also save money because they make fewer passes over the field and have less wear and tear on their machines. These factors appear to lower on-farm production costs (although there is only data at this time for one to four years, depending on how long producers have been using the technology). There are reports of a 10-percent overall increase in soybean production, but these reports are anecdotal.

From an environmental point of view, use of genetically modified soybeans also has some positive impacts. Transgenic soybeans allow producers to use no-till cultivation practices for the first time in areas of continuous cultivation. Because the soybeans have been bred to tolerate a broad-spectrum herbicide, weeds are no longer managed by plowing them under to kill them at the beginning of the growing season or by cultivating the soil during the growing season when weeds normally grow. Now, a one-time spraying of herbicides can kill weeds after the soybeans are growing. This means that organic residue is left on the surface to decompose, building up levels of soil organic matter from year to year. The organic matter on the surface also acts as mulch. It holds water like a sponge, protects the soil from the sun, inhibits weed growth, and protects the soil structure. Inputs are more effective when they become attached to organic matter and are released more slowly. In this way they are not washed away with the first rain. Since “Roundup-ready” soybeans permit the use of no-till production practices, they can reduce soil erosion, in some reports by as much as half.

On the other side of the issue, there are several concerns about use of genetically modified organisms (GMOs). First, there is a general concern that transgenic crops may cross with other plant species. This could create pesticide resistance and, as a result, super weeds or pests. In addition, the application of the same herbicide (in the case of soybeans, glyphosate or Roundup) over long periods of time will most likely create resistant weeds. This problem could very easily force producers onto an herbicide treadmill. Another concern with crops such as transgenic soybeans is that the applications of pesticides can also kill life in the soil that is essential to the maintenance of good soil structure.

It is not exactly clear what the net gain or loss is from herbicide-tolerant soybeans. Even so, there appears to be enough promise in the general approach to proceed cautiously with it. The major issue, however, is that neither Monsanto nor the producers have proceeded cautiously. There are serious concerns that insufficient information exists or is being collected about the potential long-term impacts of GMOs in general (and transgenic soybeans in particular) before they are released on a wide scale. Insufficient field trials, insufficient monitoring, and perhaps most important, insufficient transparency (access to the corporate research protocols and results that document the benign impact of the technology) were all part of the release of this GMO as well as others.

Perhaps the most important issue raised for soybeans by GMO research is how the same technology used in producing herbicide-tolerant varieties can be used to improve existing soybean breeding programs as well as the production of conventional soybeans. GMO technology could allow traits to be selected virtually overnight by comparison to the hit-or-miss techniques of traditional breeding programs.

Conventional plant breeding created a fivefold increase in new soybean varieties certified by the U.S. Department of Agriculture (USDA) between 1961–64 and 1991–94. The development of soybean varieties that tolerated low levels of soil phosphorus and high levels of aluminum was critical to the expansion of soybean production throughout the greater Amazon. Whether traditional or gene-spliced, soybean-breeding programs have implications for where and how soybeans can be planted, how productive they will be, how long it takes them to produce, and how resistant they will be to pests and climate shifts.

Processing

Very little soybean processing is done on the farm or in the immediate vicinity. Most local processing includes drying with natural gas to reduce the moisture content and blowing or screening to clean the beans of stems, dirt, rocks, or other foreign matter introduced during the harvest.

Soybeans are processed by grinding the beans and then pressing them to separate the soybean meal or cake from the oil. This entire process is called crushing. A given weight of soybeans will produce 18 to 19 percent (by weight) oil and 73 to 74 percent meal, or 35 percent protein by gross weight. This varies somewhat depending on the quality and the variety of the bean. The oil is used primarily for human consumption; the meal is used primarily for animal feed.

The United States exports about 35 percent of its raw soybeans before processing. By contrast, Argentina and Brazil add value to most of their crop; they process about 80 to 85 percent of their soybeans and export most of the products.

Argentina, Brazil, and the United States dominate world soybean markets. In 1999 they accounted for 80 percent of soybean production and 70 percent of soybean oil. Soybean oil faces intense competition from palm oil producers in Malaysia and Indonesia, who

can produce oil at about half the cost of soybean and other seed oil producers (Stringfellow 2000). The only way soybean crushers can compete with oil palm mills is by exploiting economies of scale. Consequently, the capacity of soybean crushing mills is much larger than those for oil palm. Soybean crushers can process 500 metric tons per hour. The heavy financial investment needed for crushing plants has led to growing concentration in that part of the market chain. Three multinational corporations now own more than half of the capacity in the three largest soybean-producing countries (Stringfellow 2000). Even so, it would be hard for soybean-crushing operations to compete on the price of oil by itself.

Substitutes

Two main products are made from soybeans—soybean oil and soybean meal or cake. Substitutes exist for each of these, but the various oils have distinctive tastes, and the substitutes for soybean meal have protein characteristics that make each better or worse for certain uses. Different products can be substituted broadly, but not exactly one-for-one. Ultimately, the balance of use will change due to genetic improvements or to changes in taste, price, or consumer preference. Since it is possible to change or eliminate taste or create other characteristics, price is increasingly coming to dominate the picture.

Productivity and mechanization are the main competitive advantages for soybean producers over palm oil producers. Over the past twenty-five to thirty years average soybean yields have doubled in Brazil and increased by 50 percent in the United States. In Malaysia average palm oil yields have actually declined over the past fifteen years. This has more to do with labor requirements than with genetics, however. In Brazil one worker can farm 250 hectares of soybeans, while on a mechanized palm oil estate in Malaysia one worker is required for every 12 hectares. In Brazil it takes 0.07 days of labor to harvest what will make 1 metric ton of soybean oil. In Malaysia it takes two days' labor to harvest 1 metric ton of palm oil. If yield gains and mechanization continue to favor soybean production, then the ratio of soybean oil costs to palm oil costs will fall from 2:1 to as little as 1.35:1 over the next decade (Stringfellow 2000).

Not all oils are substitutes. Lauric (oils rich in lauric acid, primarily coconut and palm kernel oil) and marine (e.g. fish oil) oil prices, for example, behave quite differently from those of the leading vegetable oils. Among the main traded vegetable oils, major deviations in Rotterdam prices (a major market where the prices of various oils tend to be quoted and compared) persist for only a short period (e.g. palm oil's large discount in 1993–94) (Stringfellow 2000). The following table shows some of the substitutions that are possible.

Table 8.1**Applications and Substitutions of Palm, Seed, and Fish Oils and Animal Fats**

Application	Competing Fat or Oil
Spreads, margarines, and vanaspati ^a	Partially hydrogenated seed oils (e.g. soybean oil etc.) Lauric oils ^b
Shortenings	Partially hydrogenated fish oils Partially hydrogenated seed oils
Confectionery fats	Partially hydrogenated fish oils Partially hydrogenated seed oils Exotic fats ^c
Frying fats	Animal fats
Ice cream fats	Lauric oils Partially hydrogenated seed oils
Applications and Substitutions of Liquid Fractions of Palm Oil	
Frying oil	Seed oils (e.g. soybean oil)
Salad oil	Olive oil Seed oils Partially hydrogenated and fractionated oils ^d

Source: Stringfellow 2000.

^a A hydrogenated vegetable fat used as a butter substitute in India.

^b Lauric oils are mid range oils in the C12 to C14 range (many natural oils are composed of a wide variety of oils from C2 to C22). They are more versatile, higher priced oils and are often made from palm oil, palm kernel oil and coconut oil.

^c Exotic fats are mostly produced from tropical oil seeds and are high (50-60 percent) in saturated fatty acids. Exotic fats include butters made from such seeds as illipe, shea, sal, mango and kokum. These fats tend to be cheaper than similar, better known fats (e.g. cocoa) and are substituted for them by food, cosmetic, and healthcare product manufacturers.

^d Fractionated oils are oils that have been separated to select for specific fatty acids. Most natural oils have a wide range of oils which make them less than ideal for many uses. It is easier if they are more uniform. For example, fractionated oils can be created with either low or high melting points.

Soybeans provide about 28 percent of the world's vegetable oil. The market substitutes for soybean oil are canola oil, sunflower oil, corn oil, cottonseed oil, palm and palm kernel oil, coconut oil, olive oil, and various animal fats. Oil palm has by far the highest productivity of any of the major vegetable oils in terms of yields per hectare. Production is five to ten times as much as soy, canola (rapeseed), or sunflower oil. Other oilseeds must make up for the lack of oil production through the income from the meal by-products. This favors soybeans in particular (Stringfellow 2000).

World production of the ten leading oilseeds (not net oil weight) was estimated at 288.2 million metric tons in 1998–99. Soybeans represent 53.7 percent of all oilseed production. Cotton represents 11.3 percent, sunflower represents 9.2 percent, canola (rapeseed) represents 12.8 percent, and peanuts (groundnuts) represent 12 percent. Table 8.2 gives totals (in million metric tons) for the top ten sources of vegetable oil.

Table 8.2 Global Vegetable Oil Production, 1998–99
(in millions of metric tons)

Type of Oil	Amount Produced
Soybean oil	24.3
Palm oil	17.2
Palm kernel oil	2.2
Cottonseed oil	3.8
Sunflower oil	9.4
Canola (rapeseed) oil	13.0
Peanut (groundnut) oil	4.4
Linseed oil	0.7
Olive oil	2.5
Coconut oil	2.8
Sub-Total	80.4
Total from 17 species*	103.7

Source: UNCTAD 1999.

*The other seven oils include corn, castor, tung, sesame, and hempseed. These five are clear (e.g. reported by UNCTAD and FAO), walnut and grapeseed are most likely the remaining two.

Many product ingredient lists indicate that a product is made from x, y, or z vegetable oil. This means that the manufacturer is free to substitute any of the listed oils, depending on the price, without changing the packaging. Partly as a result of such substitutability, canola oil has made quick strides in the market and gained considerable market share. In 1999, 27 million hectares were planted to canola (rapeseed), with the combined acreage planted in China, India, and Canada amounting to more than 70 percent of the total acreage. India and China produce 60 percent of the world's peanuts (groundnuts). The United States and Nigeria account for another 12 percent. These are used both for their oil and as a source of vegetable protein.

Cottonseed oil is a valuable by-product of cotton production, but cotton producers are not paid separately for their seed. Only in the Aral Sea area of the former USSR was cotton produced primarily for seed. In that instance the vegetable oil was a strategic raw material used as a lubricant by the military. Consumer preference, at least in most developed countries in recent years, has tended towards substituting vegetable oils for most of the animal fats used in the more obvious forms of human consumption. However, animal fats, along with coconut, palm, and palm kernel oil are used in the manufacture of numerous personal care productions (e.g. soaps, shampoos).

Soybean oil can also be substituted for fish oil in the diets of terrestrial livestock. For the most part, however, soybean and other vegetable oils cannot replace fish oil in the diets of carnivorous aquaculture species (e.g. salmon and shrimp), although many are attempting to find ways to do that. One way would be through genetically modifying the

oil-producing plants so that their seeds incorporate the feed characteristics required by marine animals.

Production of soybean meal worldwide amounted to 105.8 million metric tons in 1998–99. The top four producers are the United States, Brazil, Argentina, and the European Union. (Europe produces some soybeans but also imports the beans raw and makes its own meal.) The other main producers are China, India, Japan, and Taiwan. Globally, annual production of all oilseed meal totals about 187.7 million metric tons. Cottonseed meal accounts for 8 percent, sunflower for 6 percent, and canola (rapeseed) for 10.7 percent. With soybean meal, these three constitute more than 80 percent of global oilseed meal production (FAO 2002). Most oilseed meal is used for animal feed.

Soybean meal or cake is used primarily in the diet of livestock raised for meat, particularly chickens and to a lesser extent pigs. The main substitutes are ground corn and sorghum meal and fish meal. Cornmeal is used in many livestock operations, especially feedlot production of cattle, pigs, and chickens. The percentage of meal from different crops will vary as a result of both price and palatability. Soybean meal is considered too rich for many animals and must be “cut” by adding different meals such as corn or sorghum. Corn is a cheaper substitute, but it does not have the same nutritional profile as soybean meal. Sorghum is also gaining considerable ground as an animal ration. In particular it is used for chickens and to some extent pigs. Cassava is increasingly imported to the European Union countries for use as animal feed where it is used to cut the more protein and oil rich soybean meal. The largest international cassava supplier is Thailand.

Fish meal, bone meal, ground hair and feathers, and several other meat-packing by-products are increasingly substituted, at least in part, for soybean meal in livestock diets. There is increasing consumer resistance to these forms of substitution, however, as some meat-packing by-products have been linked directly to mad cow disease in England and France. Soybean meal is increasingly substituted for fish meal in aquaculture feeds, but no way has been found yet to eliminate the use of all fish meal. Up to this time, most competition has been in the poultry industry, where the two meals are readily substitutable. For this reason, the price of soybean meal and fish meal are relatively linked in the market place. As the aquaculture industry grows, they are likely to become less closely linked.

Market Chain

The market chain for soybeans is relatively simple. The producer delivers the product to a warehouse either at harvest or after storing to dry the beans and/or to see if the price will improve. Soybeans are stored in a grain elevator until they are transported via rail, truck, barge, or boat closer to a point of processing for storage until needed. The soybeans are then transported to the processing plants or to ports for export and processing in another country (Schnittker 1997). Table 8.3 shows the relative numbers of primary players in the

soybean market chain in the United States, as well as the change in value of the product as it moves along this chain.

Table 8.3 Players in the U.S. Soybean Market Chain

<u>Function</u>	<u>Number of Players</u>	<u>Value of Product (per metric ton)</u>
Producers	380,000	\$257
Grain elevators	Thousands	\$272
Central elevators/ports	85	\$294
Oil processors	144 (4 do most)	\$294
European Union importers	<1 dozen	\$312
U.S.-based animal feed and food manufacturers	Thousands	\$331

Source: Schnittker 1997.

There are two main processing streams, one for soybean meal and another for the oil, but many other products flow from these two original products. Processing is done by a small number of companies. In the United States, three companies (Archer Daniels Midland, Cargill, and Bunge) and one cooperative (Central Soya) control more than 80 percent of United States' soybean-crushing/oil-processing capacity and a similar share of worldwide capacity (Schnittker 1997). These companies expanded to control larger market share in the past twenty years when expensive technologies were beyond the financial capacity of many smaller firms. The dominant processors are also the leading exporters of soybeans and soybean products.

Market Trends

Between 1961 and 2000 soybean production increased by 499 percent and international soybean trade increased by 1,492 percent. During the same period the price of soybeans decreased by 53 percent. Soybeans' share of the world oilseed market has been growing steadily and now accounts for 55 percent of the total, up from 45 percent at the start of the decade (FAO 2002).

The International Food Policy Research Institute (IFPRI) estimates that world demand for meat will rise by 63 percent from 1993 to 2020, and that demand for soybeans used in part for animal feed will increase by 66 percent by 2020. This is greater growth than for other cereals, which combined are expected to increase by 40 percent over that period (Schnittker 1997).

Soybean meal has comprised about two-thirds of the value of soybeans in recent years, with oil about one-third. This situation developed over the past thirty to forty years as the demand for protein for animal feed increased rapidly and as the production of other oil-rich seeds such as palm oil, canola, and sunflower weakened the demand for soybean oil (Schnittker 1997).

In a number of fast-growing developing economies (e.g. India, China, Pakistan), growth in production of vegetable oils lags behind growth in consumption. As a result, imports of such oils are growing fast. However, even in developed countries demand for vegetable oils is growing strongly as lifestyle changes (e.g. more fast food, ready-to-eat snacks, and processed foods) also increase consumption of vegetable oil (Stringfellow 2000). Demand growth for vegetable oils in developing and developed countries will drive production and trade by 2010 to about 150 percent of 1999 levels.

The 1997 Asian financial crisis stopped the soybean market increases for both oil and meal in their tracks. The second factor that affected the global market was the liberalization of farm policies in the United States. This, combined with high prices in 1997, created the conditions for a record harvest in all the major soybean producing countries of the Americas.

Subsidies, price supports, market barriers, and other policies aimed at protecting soybean producers or food processors in developed countries are ultimately regressive taxes. That is, they are wealth transfers from the entire population of those countries to specific producers and processing industries. It is not clear if this practice will be tolerated once the full impact of such policies are understood by the taxpayers of developed countries.

During the past ten to twenty years China has gone from being a soybean exporter to being the world's largest importer of whole soybeans and oil and a large importer of soybean meal. It is this increased demand that is stimulating the production in the Amazon and other remote areas. This trend was due, at least in part, to the direct investment of the United States Soybean Producers' Association, which spent considerable time in China demonstrating the value of soybean meal in animal and aquaculture rations. The association's goal was to eliminate China as a possible competitor producing soybeans for the global market by increasing domestic demand so much that the country would become a net importer. While China has become one of the largest consumers of soybeans in the world, it is also producing increasing quantities of soybeans and has encouraged producers to switch to soybeans from other crops such as tobacco.

The other factor that is now affecting the soybean market is consumer concern with GMOs in general and transgenic soybeans in particular. Responding to consumer concerns, the European Union has required that products containing GMOs be identified for consumers. In addition, the European Union is attempting to require that GMO soybeans be separated from other varieties so that those purchasing them for feed or as ingredients can make a choice about the products they buy and that ultimately make their way to the consumer. As a consequence, the overall trade statistics are clear—markets for soybeans from the United States have declined due to the inability or unwillingness to

segregate GMO from traditional soybeans. Consequently, where GMO soybeans had a slight market preference in the late 1990s (even up to 30 cents per 27 kilogram bushel), by 2000 non-GMO soybeans were already beginning to fetch a higher price in the marketplace (Stringfellow 2000). Producers in the United States are responding and some of the land currently planted to GMO soybeans will be replaced with traditional varieties. This in fact has created market scarcities for seed for traditional varieties and created the need for storage facilities that can keep the different soybean varieties separate.

At this point, countries that can guarantee that they are not producing or exporting GMO soybeans can capture a premium price in the marketplace because of consumer concerns in Europe and Japan about transgenic organisms. China, by contrast, has said it is not concerned about transgenic soybeans.

Aggregate statistics represent thousands of individual purchase decisions. For example, the French grocery store chain Carrefour recently announced a sizeable contract to purchase Brazilian soybeans to provide fodder for their meat suppliers. In this case a retail chain, responding to consumer demand, is working directly with its suppliers to produce a product that it will be able to sell to its customers. They have insisted that the product be GMO-free.

At the same time, the European Union recently approved the ban of animal feed made from animal bone and meat powders (Tengnäs and Nilsson 2002). This decision is likely to lead to an increase in the consumption of soybean meal for animal feed. However, the fear of GMOs may be no less than that of mad cow disease, which spawned the ban on animal products in feed in the first place. It is likely that this will ultimately dampen demand for soybean meal.

Since 1994 soybean oil and palm oil have been priced almost exactly the same. Since they are substituted for each other, their prices are linked. A scarcity of one triggers purchases of the other. The price of soybeans at this time is declining. This appears to be related to two factors—the increased production of soybeans in Latin America and China and the declining price of palm oil based on increased planting in Indonesia, Malaysia and Papua New Guinea.

Another factor has affected overall soybean market trends. Each soybean product tends to have an impact on the pricing of the whole set of products. If the price of oil is high, then the price of meal can be lower to gain market share. If, however, the price of oil is low, then the price of meal must be high or soybeans decline in value. Unlike most oilseeds, soybeans contain only about 18 percent oil. It is not profitable to produce the oil if there is not also a market for the meal. The meal is, in contrast to most oilseeds, quite high in protein—from 44 to 48 percent.

Environmental Impacts of Production

In the United States and the European Union, the production of soybeans poses a few rather distinct environmental problems. These have to do with the use of agrochemicals

in production and the degradation of soil through the use of chemicals, erosion, or compaction. Runoff resulting from soybean production can include high levels of agrochemicals, suspended soil, and organic matter. This can be a major source of freshwater and groundwater contamination. Elsewhere in the world the major environmental problems associated with soybean production include the conversion of natural habitat, soil erosion, and the ever-increasing use of pesticides.

Conversion of Natural Habitat

In the United States and Europe the decision to plant soybeans does not usually entail a decision to clear natural habitat; soybeans are produced, by and large, on areas previously used for agriculture. Producers have merely made a choice to produce soybeans rather than another crop that had been grown previously. This is not the case in many tropical countries, however, where the cultivation of soybeans often is part of the process of converting extensive areas of natural habitat to agriculture for the first time. This is true of Brazil, Argentina, Bolivia, Paraguay, and Cambodia. In these instances, producing soybeans destroys natural habitat and nearly all the flora and fauna found there. In Latin America soybean cultivation has taken place at the expense of natural savannas and tropical forests.

In addition to direct habitat conversion, soybean production in pristine areas also requires the construction of massive transportation and other infrastructure projects. The infrastructure developments unleash a number of indirect consequences associated with opening up large, previously isolated environments to population migration and to other land uses. This infrastructure contributes directly and indirectly to habitat conversion. In Brazil, for example, plans are underway to build eight industrial waterways, three railways, and an extensive network of highways. Such infrastructure is not used just for soybeans. Estimates suggest that collateral impacts may be as much as six times those resulting directly from soybean production, particularly in areas like the Amazon where isolation had previously been the limiting factor for development (Fearnside 2000).

Some soybean producers clear forests themselves. Others buy the land from small producers, often colonists, who have already cleared it. These same small producers then move further into the frontier and clear more land. In Brazil, soybean cultivation displaces eleven agricultural workers for every one finding employment in the sector. In the 1970s, 2.5 million people were displaced by soybean production in Paraná state and 0.3 million in Rio Grande do Sul. Many of these people moved to the Amazon where they cleared pristine forests (Fearnside 2000). More recently, the expansion in the cerrado involves the displacement of very few people because the area has not been widely inhabited.

In Brazil the savannas and cerrados are the most at risk. These areas have biodiversity that rivals equivalent areas of Amazonian forests, but only 1.5 percent of such lands are in federal reserves. Unfortunately, they can be easily converted into vast expanses of soybean fields. Even during the first year, however, agrochemicals must be provided for the crop to be financially viable. The soils are often so poor that within two years,

virtually all nutrients are provided through applied lime and fertilizers. The soil is stripped of virtually all fertility and only serves to hold up the plants.

Soil Erosion

Globally, some progress is being made on the issue of soil erosion. One 1996 study in the United States showed that soil erosion associated primarily with soybean and corn production in the Midwest fell from 37.5 metric tons per hectare in 1930 to 19.5 metric tons per hectare in 1982 and to 15.75 metric tons per hectare in 1992 (Schnittker 1997). This rate is easily still a few times greater than is sustainable, (defined as a creation of soil greater than or equal to that lost through erosion).

Despite the progress, there is reason for concern as lands classified as “highly erodible” are now being used for soybean production. In the United States, the Conservation Reserve Program actually paid producers to take highly erodible land out of production. It now appears that the development of herbicide-tolerant (“Roundup-Ready”) soybeans has encouraged many producers to plant at least some of those lands again. The soybean varieties genetically modified to tolerate herbicides allow producers to employ no-till and conservation tillage production systems to minimize erosion, even on the most erosion-prone areas. However, the net environmental impact of this change in cropping has yet to be determined. The chief fear with the highly erodible lands is that, despite improved techniques, soil erosion will once again become a problem.

The Brazilian National Development Bank has warned that “without well-defined technical criteria” the soil in many areas of the Amazon could be rendered unusable by soybean cultivation. Soybean production also causes soil compaction. In Bolivia, where soybean cultivation has been increasing since the 1970s as a result of investments in crop substitutes for coca production, degradation is already severe. Initially, soybeans could be cultivated without fertilizer or lime applications. By the late 1990s, however, more than 100,000 hectares of former soybean lands were abandoned to cattle pasture because the soil was exhausted. The three Mennonite settlements that had farmed soybeans had moved further to the north to clear more forests to, once again, plant soybeans.

Groundwater Contamination from Fertilizers and Pesticides

In the United States the Environmental Protection Agency (EPA) has recently acknowledged that agriculture is the major source of surface water quality problems in 72 percent of impaired rivers, 56 percent of lakes, and 43 percent of estuaries (US-EPA 1994, as cited in Soth 1999; Faeth 1996). In the United States the main herbicide used with GMO soybean production is glyphosate (trade name Roundup). While glyphosate has been touted by the manufacturers as benign, and they can back up their claims with research they have supported, other studies suggest otherwise. For example, they allege that the chemical has been linked to reproductive disorders, genetic damage, liver tumors, disrupted embryo development, and developmental delays in mammals (e.g. Cox 1998).

While some producers claim that one application of herbicide is all that is needed for an entire growing season with herbicide-tolerant soybeans, studies show that both the total

amount of herbicide used and the number of applications have increased. Chemical usage summaries from the National Agricultural Statistics Service of the United States Department of Agriculture (USDA 1991) show that in the United States, total herbicide use on soybeans increased from 56.4 million pounds in 1995 to 75.2 million pounds in 2000. The use of glyphosate (Roundup) increased from 6.3 million pounds to 41.8 million pounds in the same period. In 1995 glyphosate was used on 20 percent of the soybean crop, but by 2000, just four years after the 1996 release of Roundup-Ready soybeans, it was used on 62 percent of the crop (Tengnäs and Nilsson 2002). Furthermore, the number of applications increased from one application per crop to 1.3 applications.

There is concern (but not yet evidence) that agrochemicals such as the herbicides trifluralin (Treflan), lactofen (Cobra), fomesafen (Reflex), bentazon (Basagran), imazethapyr (Pursuit), sethoxydim (Poast), and clethodim (Select) will contaminate lakes and lagoons in the Brazilian Amazon River flood plains. During the dry season, the waterways dry up and any contamination within the separate water bodies would become more concentrated (Fearnside 2000; Leibold 2001a).

In the Brazilian Amazon high humidity and heavy rains have already caused the spread of fungus and blights. This, in turn, is resulting in the increased use of fungicides. Similarly, as production continues in the same area over a number of years, pest populations will increase, which will be followed by an increase in the use of chemical controls. Because Brazil has no frost, the different pests will adjust more rapidly to whatever chemicals are used to prevent them than they do even in the United States, where pests have rapidly developed resistance to the chemicals used to control them.

The FAO and others estimate that 25 percent of all pesticides used in Brazil are used in soybean cultivation, and that in 2002 an estimated 50,000 metric tons of pesticides were used by Brazilians on soybeans (World Bank 2002). Because of the rapid expansion of area planted to soybeans, pesticide use is increasing at a rate of 21.7 percent per year. However, the growth in pesticide use is increasing even faster than the growth in either area cultivated or overall soybean production. While part of this can be explained by the lack of frost and pests developing resistance to pesticides due to increased use, there are other factors involved. Production is expanding into areas with insufficient labor and pesticides are used to reduce labor costs. Areas planted to soybeans are becoming larger and therefore mechanization makes the application of pesticides more cost-effective. More work needs to be done on analyzing the full range of agrochemicals used in the cultivation of both traditional and GMO soybeans as well as their long-term movements in the environment, their impacts, and the development of resistance to them.

Extraction of Limestone

In Brazil, the lime requirements of growing soybeans in the Amazon alone could lead to considerable destruction of natural resources. Lime (a source of calcium) is applied to soils to counteract acidity, because neutralizing soil acidity makes existing nutrients more available to plants such as soybeans. The mining of limestone requires the removal of considerable overburden (natural cover, soil, etc.) to gain access to limestone deposits. In

addition, large amounts of energy are used to cook the limestone and make it into agricultural lime. In the Brazilian savanna areas, 4 to 6 metric tons per hectare of lime are required to produce soybeans. In cleared forest areas, only 2 metric tons per hectare of lime are required, initially at least (Fearnside 2000). This raises two issues. The first is the production and transportation of the lime itself. The second issue is the incentive to shift production into cleared forest areas that do not require the initial application of so much lime.

Better Management Practices

There are a number of conservation strategies that can reduce the impact of soybean production. These include creating protected areas in areas of soybean expansion and using zoning to restrict expansion to degraded or abandoned agricultural areas.

The identification and adoption of no-till practices can reduce the soil erosion caused by soybean production, as can linking the adoption of such practices to government subsidy programs. A related policy initiative to reduce the harmful impacts of the industry is to remove subsidies that encourage soybean expansion for artificial markets. Clearly, one conservation strategy should be to identify and analyze the implications of soybean expansion for natural habitat. Finally, command and control regulatory systems can reduce the environmental problems associated with soybean cultivation. Each of these strategies is discussed separately. However, their cumulative impacts are greater than their individual ones.

The strategies that are most appropriate to reduce the impacts of soybean cultivation will vary considerably from one country to another. China has produced soybeans longer than any other country. Today, the country's production is seriously affected by pests. Some 8,800,000 hectares of land have been affected by losses estimated at some 32,900 metric tons. In one of the areas most used for soybean production, the following measures are taken to prevent diseases: crop rotation, deep plowing, late planting, manuring, and the application of pesticides as needed (Tengnäs and Nilsson 2002). These strategies, at the other end of the spectrum from input-intensive no-till cultivation with or without transgenic varieties, suggest that techniques will vary widely from country to country and will depend on specific conditions and pests.

In the United States, the better management practices (BMPs) that have evolved are quite different. In this country precision agriculture and the targeting of agrochemicals to address specific needs have resulted in a reduction of the overall average use of chemical inputs per hectare. Likewise, soil erosion has been reduced by standard conservation techniques including terracing, strip cropping, planting cover crops, maintaining waterways, and improving road construction and machine access. Organic matter content in the soil has been improved through mulching and conservation tillage programs such as reduced tillage and spring tilling. No-till production leaves virtually all crop residues on the surface while reduced tillage (or low-till) leaves some 15 to 35 percent of crop residues on the surface (Schnittker 1997). Conservation tillage provides more ground

cover, more available waste grain for food, and less disturbance of nesting sites than conventional tillage. All of these practices have a net positive impact on biodiversity and ecosystem functions. Most of these practices also increase yields and profits.

There are a number of impediments to the adoption of BMPs, however. At a recent meeting in Iowa hosted by Natural Resources Defense Council (NRDC 2001), a number of issues were identified that affect overall pesticide use. Perhaps the most important is that the adoption of BMPs requires a greater time commitment to management, yet farm size is growing in most soybean-producing areas so there is less time available to devote to each hectare of production.

Create Protected Areas and Easements

The creation of protected areas on expanding soybean frontiers could be an essential source of protection for biodiversity and fragile ecosystems in areas that are often not suited for long-term soybean production. In Asia and Latin America where soybean production is expanding into tropical savannas and forests, one strategy would be to identify key biodiversity sites and work to set them aside as protected areas as a condition of the further expansion of soybean production. For example, in the cerrado of Brazil less than 2 percent of the land is under any form of protection. In the Atlantic coastal forest of Paraguay there is a similar lack of protection.

It is also possible that individual producers would choose to set aside areas of their farms that are less productive because they are simply not profitable to farm. Focusing on more productive areas may allow such producers to increase net profits while reducing overall impacts.

Another way to accomplish many of the same objectives of permanent protection would be through conservation easement programs. In this strategy, producers would be paid (by a government or some other interested party) some portion of the value of their land if they agreed to adopt a specific BMP approach. Such a system might specify preferred practices as well as those to avoid. Or the approach might focus on results and leave it to the producer to figure out how to achieve them. Practices that could be encouraged include getting producers to leave hedgerows intact, not to destroy waterways, and to reseed or otherwise repair waterways where soil erosion has occurred. Other requirements could include prohibiting the use of certain classes of pesticides or insistence on the use of conservation tillage or no-till production.

An example of a conservation easement is the Conservation Reserve Program (CRP) in the United States, which has allowed for a considerable reestablishment of biodiversity on areas of former cropland. In this case, the government purchases a “no-use” right for a period of ten years on some 14.5 million hectares, at least half of which are highly erodible. In some cases, trees have grown back in these areas, and it is doubtful that they will be used for crops even after the end of the ten-year contract. In part this happened because the payments were higher than necessary. The first CRP contract payments often exceeded the local rental value of the land by 30 to 50 percent. About half of the land in the initial program was highly productive and was included more for political reasons

than environmental ones (Runge and Stuart 1998). Ways to improve the program include targeting leases only for highly erodible areas, identifying new areas that would form the basis of an overall conservation strategy, encouraging farmers to plant trees or to allow trees to grow and collect carbon sequestration payments as well, and paying less for conservation easements on lower-quality lands.

In many parts of the world soybean crops are grown amongst other crops, not surrounded by natural habitat. In these situations, permanent protection may be irrelevant. Instead, zoning regulations could promote soybean production on lands already in agricultural production or on degraded or abandoned land, rather than on environmentally sensitive land.

Use Zoning to Restrict Agricultural Expansion

In Brazil, where soybean production is expanding rapidly and on a large scale, there is little reason for expansion into natural habitat. First of all, much of the natural habitat areas are not suited for sustained soybean production. If the price of soybeans continues to decline, the area suitable for competitive production will decline even more. Such areas should be zoned so that they will not be used for soybean production. Appropriate financial analyses showing the mid- to long-term financial costs of farming such areas could help generate the political will (both with producers and, more broadly, with civil society) to zone such areas from soybean production.

In addition, Brazil should identify areas that should be zoned for production. Brazil has less than 14 million hectares in soybean production. However, more than 5.5 times that amount of land is abandoned or degraded agricultural land or pasture. Not all of this land is suited for soybean production. Some is hilly or badly eroded, and some was not cleared well. These lands would be more expensive to bring back into production. However, much of the land could be made productive again with up-front investments that are no larger than those required for clearing land. Producers in the cerrado have shown that degraded pasture and agricultural land can become productive soybean lands within two to five years. Furthermore, such land is cheap to buy and within as little as three years can be worth three times the purchase price. The financial case for rehabilitating such lands, however, has not yet been made. A few case studies could be very useful to convince producers, government officials and even lenders that such strategies are not only viable but profitable and creditworthy.

Adopt No-Till or Conservation Tillage Practices

No-till production is increasingly common in both Brazil and the United States. In Brazil it has increased in the cerrado from 180,000 hectares in 1992 to 6,000,000 hectares in 2002. Producers have found that no-till techniques within certain planting sequences each year as well as longer term crop rotations allow producers to increase production by 10 percent. However, they also allow producers to reduce use of lime, pesticides, and fungicides by 50 percent or more, and the use of other chemicals by 10 percent. In short, the net return per hectare is almost 50 percent higher than that of producers using conventional methods.

Less machinery is required for no-till planting than for conventional tillage. Even so, for farmers who have already invested large amounts in machinery for conventional cultivation, this could be a burden. In addition, while no-till cultivation requires less machinery, it requires some specialized pieces that would have to be purchased. However, the new machinery could be phased in over time or custom planters could be hired to plant the crops. In general, there do not appear to be any significant financial barriers to the adoption of no-till technology. If anything, the main barriers are cultural—producers are not comfortable with the new technology because it runs counter to how they have farmed in the past.

In addition to the financial returns from no-till, there are also a number of conservation gains. In Brazil conventional tillage typically causes soil losses of some 23.6 metric tons per hectare per year. With no-till, soil erosion can be reduced to as little as 5.6 metric tons of soil per hectare per year. The rainfall runoff on fields under conventional tillage is typically on the order of 137.6 mm/month. With no-till practices the runoff can be reduced to about 42.4 millimeters. The reduced runoff is the result of crop residues on the soil surface slowing the movement of water, allowing more time for the water to be absorbed by the soil and stored for later plant use or released more slowly over time.

There are also benefits at the landscape or ecoregional level. These have been estimated for the cerrado of Brazil, where the practice is most common, and are shown in Table 8.4. The study summarizes the estimated benefits of adopting no-till agriculture techniques in Brazil on 35 percent and 80 percent of a total cultivated area of 15.4 million hectares.

While such studies are always somewhat theoretical, the authors did not include increased yields as a likely positive impact. Even so, the numbers are interesting and give insights into the possible benefits of this practice if adopted on a wide scale. For example, many of the benefits are mutually reinforcing—e.g. more organic matter means better utilization of other inputs (fertilizers, pesticides, water, machinery, energy and irrigation systems) and thus fewer expenses for them or impacts from them. The findings also suggest that government support for the conversion to no-till practices would be more than offset by societal benefits. For example, fewer roads would be washed out from runoff, and there would be less siltation of rivers and lakes and fewer impacts on local sources of drinking water. All of these benefits of no-till would result in fewer government expenditures to fix the impacts of conventional tillage.

Table 8.4 Annual Economic Benefits of No-Till Adoption in Brazil
(in millions of U.S. dollars)

Categories of Impacts	35% No-Till Adoption	80% No-Till Adoption
On-farm benefits	356.1	791.4
Incremental net benefits of no-till versus conventional tillage	332.9	739.7
Irrigation pumping economy	23.2	51.7
Off-farm reductions in public expenditures	62.1	138.0
Maintenance of rural roads	48.4	107.6
Municipal water treatment	0.5	1.1
Incremental reservoir life	9.2	20.4
Reduced dredging costs in ports and rivers	4.0	8.9
Off-farm environmental impacts	184.1	409.1
Greater aquifer recharge	114.4	254.1
Carbon credits for diesel economy	0.6	1.4
Irrigation water economy	6.6	14.8
Carbon sequestration in soil	59.5	132.2
Carbon sequestration in surface residues	3.0	6.6
Benefits to integrated no-till and livestock systems	784.0	1,742.2
Total benefits	1,386.3	3,080.7

Source: Landers et al. 2001.

The current rate of soil erosion in the United States (which averaged 15.75 metric tons per hectare per year in 1992) could be halved with the adoption of no-till cultivation and other basic conservation practices (Schnittker 1997). The reductions described earlier in the discussion of soil erosion were not accomplished by growing fewer row crops. In fact row crop cultivation has intensified in the United States. Rather, investments in a variety of conservation measures such as constructing terraces, strip cropping, contour tillage, and rotations led to the reduction in soil erosion rates. By 1994 nearly 40 percent of crop acreage in the United States was under some form of conservation tillage compared with only 3 percent in 1984. No-till cultivation was in use on 12 percent of row crops in the United States, and other forms of reduced tillage on 26 percent of planted crops. In addition, about 18 percent of the most highly erodible acres were entered in the Conservation Reserve Program (CRP), where producers were paid not to cultivate those areas (Schnittker 1997).

In the future it may be possible to provide payments to encourage particular land-use practices that link conservation tillage to carbon offsets. Conservation tillage offers the possibility not only of reducing carbon loss from the soil as a result of cultivation, but also of increasing soil carbon in the form of organic matter, with positive impacts on both soil productivity and greenhouse gas reductions. For example, Reicofsky (as cited in Tengnäs and Nilsson 2002) reports tests in which carbon loss following conventional

plowing was 13.8 times as much as soil that was not plowed. Carbon loss from four different conservation tillage methods averaged 4.3 times the loss from unplowed soil (Tengnäs and Nilsson 2002). Another way to structure such a program would be to pay producers with subsidies for building up specific amounts of carbon in their soil.

Encourage Fallowing and Crop Rotation

Enriched fallowing and fallowing with crop rotation are BMPs that can help rejuvenate soils that have been degraded. Fallowing (planting a cover crop and then leaving the land out of production for a period of time) allows the land to recover. It can be an economically profitable investment rather than a period of financial loss without production. Fallowing builds up organic matter in soil, creates surface litter that acts as mulch, and builds up populations of beneficial soil microorganisms. Furthermore, the deep roots of some cover crops can bring to the surface nutrients such as potassium and phosphorus that are trapped in deeper recesses of the soil.

Periods of fallow and crop rotations can include nitrogen-fixing plants such as legumes, or pasturing livestock on the land, to build up significant soil reserves of nitrogen. Fallowing and crop rotation can generate annual savings that are equivalent to the profits of annual production. Fallowing also increases habitat, albeit temporarily, for many different species. However, if fallowing is undertaken on a larger scale, then habitat can be maintained within a landscape that will benefit many different species. Finally, when an area is returned to cropping after fallowing, yields increase and pesticide and fertilizer costs are reduced.

Minimize Fertilizer and Pesticide Use

Practices to reduce fertilizer, insecticide, and herbicide use are certainly possible. As described above, planting legumes as part of a fallow or crop rotation system can reduce the need for applied nitrogen fertilizers. Another way to minimize the use of agrochemical inputs is to adopt precision fertilization and pesticide application systems. These systems avoid excessive applications by targeting the timing and the location of applications on an as-needed basis. In some cases, pesticides can be applied through irrigation systems. To minimize the use of fungicides, microbial inoculates that diminish the impact of pathogenic fungi can be sprayed. While no-till has been shown to reduce the use of some agrochemicals, even some of the most harmful ones, it does seem to lead to an increased reliance on glyphosate.

Another factor that affects agrochemical use in the United States is land tenure. About 50 percent of farmland in major soybean-producing states like Iowa is rented (NRDC 2001). Landowners often prefer to rent to those who maintain “nice, clean fields,” i.e., ones treated with herbicides so they are free of weeds.

Increased management and time commitments are major issues for producers. Producers are reluctant to adopt precision chemical applications if they require more time. One farmer reported herbicide reduction techniques took about 1 hour per acre for soybeans (1.3 hours per acre for corn) and saved \$12.50 to \$17.50 per hectare (\$5 to \$7 per acre).

Using ridge-till cultivation (a form of reduced tillage) reportedly saves producers \$12.50 to \$17.50 per hectare (\$5 to \$7 per acre) as well. Producers were not willing to maintain these practices because the labor required was at the busiest time for the producers and their families, and it was too expensive to hire others to do the work (NRDC 2001). From their point of view increased labor costs exceeded other savings. Reducing the overall time required for such practices (or increasing the costs of not adopting such BMPs through taxes or pollution fines) would encourage farmers to make the investment.

Incentives for producers to reduce pesticide applications could include cost-share funds where the government agrees to cover part of the cost, one-on-one technical assistance, insurance premiums that underwrite the risk of crop damage or yield reduction, “green” product labeling, and the development of retail markets for low-pesticide products. In both Brazil and the United States it has been suggested that pesticide applicators, whether contractors or landowners, should be trained. There have also been formal calls for licensing applicators. (This is already required for restricted-use pesticides in the United States, but not for those chemicals classified for general use.)

Reward Custom Applicators for Using BMPs

The rise in use of custom applicators is partly in response to increased pesticide regulations. By law, use of restricted pesticides is limited to licensed applicators. If producers don’t want to go through the bother of becoming licensed, then they have no choice but to hire custom applicators. Such applicators need to be given strong incentives to adopt BMPs and to reduce the overall impact of both their practices and the chemicals they apply.

The issue, however, is not entirely related to regulations. Labor costs are increasing, which makes management more expensive. As a consequence, in the United States, at least, there is a rise in the use of custom applicators. For example, custom applicators now apply 50 to 60 percent of all pesticides in Iowa. In general, applicators are not committed to BMPs (NRDC 2001). Rather they are often interested in getting through the job as quickly as possible because they are paid by the area sprayed.

Although careful crop rotation can reduce herbicide and fertilizer use, to work effectively it might take three to four crops. The economics of subsidies and the lack of markets for small grains in the United States discourage crop rotation, however (NRDC 2001). Instead, producers are increasingly relying on a package of services provided by custom applicators to reduce the pest problems that result from continuous soybean cultivation or more lucrative soybean and corn rotations. The package includes a rate of pesticide application per hectare as determined by the applicator but also based on manufacturer recommendations. These recommendations are notoriously high.

In Iowa, the state’s extension service has shown producers that insecticide rates could be reduced by 50 to 75 percent through integrated pest management (IPM) practices (NRDC 2001). Producers and custom applicators will reduce application rates based on their own or a trusted source’s experience. However, both will be concerned about potential liability for a damaged or unprotected crop. Producers will only adopt BMPs such as IPM

if they believe that they will result in a good crop without undue pest problems and an average or better yield.

Custom applicators provide services on a wide range of issues from financing to delivering the crop to market. Because they are increasingly part of the application of various inputs, they must be involved in the development of viable reduction strategies. Custom applicators are trusted by producers. It is assumed that they have the latest information and research results, are well trained, and have the latest equipment that is dedicated to the task. In general, custom applicators will incorporate BMPs into their programs if they perform well for the producers and thus do not threaten the reputation of the applicator (NRDC 2001).

Link Adoption of BMPs to Government Subsidy Programs

Once better practices have been identified, they should be encouraged. One way to do this is to make the adoption of BMPs one criterion on which governments base producer payments or subsidies. Making such payments contingent on compliance with the adoption and implementation of BMPs would insure that the payments achieve concrete results that are better for society as a whole as well as producers. In the United States, this could be done through the existing Conservation Reserve Program; in the European Union it would fall under the Common Agriculture Policy (CAP). Brazil could link credit for rehabilitating degraded or abandoned land to the guarantee that BMPs would be adopted and used by producers.

Many countries already make some subsidies and producer payments conditional on specific activities required of producers. Pressure could be applied to help insure that there is political will to link improved practices with such payments. It is also possible that BMPs could serve as the basis for a labeling system, spurring consumer preference and perhaps resulting in slightly higher payments to producers. For example, certified non-GMO soybeans already command a premium on U.S. markets and are virtually required for market entry in Europe and Japan. Organic soybeans command an even higher premium.

Government-sponsored conservation programs could be more effective if they linked government support to proven conservation results that also make production systems more sustainable over time. If subsidies are going to be a socially meaningful part of agricultural policy rather than just a transfer payment or an overall price support, then they should at least guarantee a variety of public goods. Broadly, positive environmental impacts would fall into this category. This approach is not without precedence in the United States and other countries. In the United States, for example, producers have been required to comply with a range of different conservation programs in order to receive benefits. Such programs have been responsible for the following:

- the increase of conservation tillage since 1989;
- the continuation of the carrot-and-stick approach that producers have known since the 1930s;
- the development of criterion used to determine subsidy payment eligibility;
- the rationale for continued federal incentive payments to producers after 2002;

- the tightening up of the administration of the program each year.

With the exception of the first item, however, the actual on-the-ground results have been far less than might have been hoped.

Eliminate Soybean Subsidies and Market Barriers

Subsidies aimed at encouraging soybean production and export irrespective of the environmental cost or current market demand for the product should be eliminated. Price supports for soybeans in the United States are precisely the kind of subsidy that fly in the face of unregulated markets and that ultimately will cost most of society a lot, yet ultimately will fail to protect American producers from cheaper soybeans from other parts of the world, especially Brazil.

Virtually no country is immune from harmful subsidies. Take Brazil, for example, a country with a number of advantages for the production of soybeans. In Brazil several subsidies are being considered. The governor of Roraima, the northernmost state in Brazil, has proposed a twenty-year tax exemption for all soybean producers (Fearnside 2000). The idea is to increase production from close to zero in 1999 to 200,000 hectares by 2005 with an overall investment of some U.S.\$300 million. Production would be exported by road through Guyana. If the road through Guyana is completed and paved, then considerable logging would probably take place in that country as an indirect consequence of soybean production. It will be essential to oppose these subsidies if the harmful environmental impacts of soybean production are to be checked.

Likewise, market barriers that tend to protect domestic producers or processors such as those in Europe should also be eliminated. Such programs encourage production in countries that are less well suited and overall are less productive. They also cause producers from more productive countries to attempt to cut costs even more (often at the expense of the environment) so that they can compete with domestic producers (e.g. Europe or China) that are protected with import duties or tariffs.

Outlook

Brazil and Paraguay are the two countries where soybean production is expanding the quickest and, at least in the case of Brazil, where large amounts of land suitable for production are still available for expansion. Many strategies are being pursued to encourage production, but little is known about what environmental impacts might result if such strategies are successful. In addition, there has been little thought to the overall market impacts of increased soybean production. For example, what would happen to the global price for soybean meal and oil? What would happen to lands that had been cleared of native habitat to plant soybeans if the markets crash?

In the rush to make money from soybean production, many states in Brazil are trying to encourage investments to support the industry. For example, plans for soybean production in the state of Acre, in western Brazil, are used to justify the construction of

the Road to the Pacific (Fearnside 2000). No study, to date, has shown what the environmental impact of such a road might be, much less whether trucking soybeans over the Andes could even compete economically with American soybeans in the Asian market.

Three factors appear to be shaping soybean production and expansion—animal protein consumption, subsidies, and the global economy. Soybean meal is the feed of choice for animals in a world where demand for animal sources of protein are growing very rapidly. So long as that demand increases, the production of soybeans will increase. Where and how soybeans are grown has more to do with agricultural subsidies and market barriers than other factors. While such policies will change, it is not likely to be in the near term, and it is not likely that the new policies will undermine current production, at least in the United States. Finally, both consumption and subsidies are directly linked to the global economy. If the global economy undergoes a significant downturn, then the ability of consumers to consume animal protein and the ability of governments to continue to support subsidies are both likely to be eroded. This would affect overall demand for soybeans as well as production.

Resources

Web Resources

www.unitedsoybean.org

Additional resources can be obtained by searching on “soy”, “soybean”, or “soy oil” on the WWF International Intranet:

<http://intranet.panda.org/documents/index.cfm>

Contacts Within the WWF Network

Lucy Aquino, WWF Paraguay Project Office (alaquino@conexion.com.py)

Jason Clay, WWF-US (jason.clay@wwfus.org)

Lou Ann Dietz, WWF-US (louann.dietz@wwfus.org)

Mikel Insausti WWF European Policy Office (mikel@wwf.org.br)

D'Alembert de Barros Jaccoud, WWF-Brazil (dalembert@wwf.org.br)

Frans Schepers, WWF-Netherlands (fscopers@wwf.nl)

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