Assessment of the Technology of Genetic Modification in Light of its Socio-Economic Implications

Valentina Lootens

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ASSESSMENT OF THE TECHNOLOGY OF GENETIC MODIFICATION
IN THE LIGHT OF ITS
SOCIO-ECONOMIC IMPLICATIONS

An internship project submitted in partial fulfillment
of the requirements for the degree of
Master of Science

By

VALENTINA LOOTENS
B.A., Voronezh State University, 2003

2006

Wright State University
I HEREBY RECOMMEND THAT THE PROJECT PREPARED UNDER MY SUPERVISION BY Valentina Lootens ENTITLED Assessment of the Technology of Genetic Modification in Light of Its Socio-economic Implications BE ACCEPTED IN PARTIAL FULFILLMENT FOR THE DEGREE OF Master of Science.

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ABSTRACT

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Assessment of the Technology of Genetic Modification In Light of Its Socio-economic Implications

Since Watson and Crick discovered the “double helix” in 1953, the arguments about the benefits and danger of genetic modification remain largely unanswered, particularly in the relation to food supply. Today, genetic modification or genetic engineering are global issues. Governments, scientific organizations, corporations, research institutions, and scholars hotly dispute the advantages and disadvantages of GM technology. However, unfortunately, the population at large is left in darkness about this new technology and its consequences for human health, environment and society. Moreover, genetic engineering creates a special problem: unlike many new technologies it is irreversible. Once introduced into the food chain, GM gene is hard and costly to trace and impossible to revert. The long-term outlook can be devastating: unleashed and unmanageable GM traits will forever change our food, nature and, thus, ourselves.

Analytical models and the field data raise alarming questions about the long-term effects of GM on human health, coexistence of different farming methods, extinction of certain species, disruption of the food chain, pollen cross-contamination, new allergies, mutations, new diseases, disadvantaged communities, inability to practice religions and beliefs, etc.

The results of this study are alarming: long-term effects of the rapidly diffusing technology of genetic modification are largely unknown, short-term effects are disagreed upon, and there are no signs of large societal benefit to date of this technology. This brings the question: Are biotech’s perceived benefits worth the exposure to a potential large-scale catastrophe?
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Globalization, economic growth, and rapid technological changes are signs of the twenty first century. The world is “growing” in several directions: technological, economic, political, social, and cultural. In light of the constancy of change, new ideas, technologies, and products have very high value. Businesses of all kinds strive for efficient production in order to obtain the competitive advantage. The accumulation of capital, broadly defined to include physical, human, and knowledge capital, has become the main goal of development. On the other hand, in the social sphere there are issues such as poverty, malnutrition, and a rapidly growing population on the planet. The comparatively new technology of Genetically Modified Foods offers a solution to hunger and related social issues associated with economic development and integration.

**Purpose of Study**

This study examines the development and diffusion of GE and GM technologies and its potential health, environmental, social, cultural, and economic implications. The primary thesis of this study is that nations (particularly the U.S.) are pursuing a potentially dangerous and reckless approach by embracing and promoting GE and GM technologies without appropriate concerns for their potential side effects. The technologies are diffusing very rapidly yet legitimate concerns about their long-term effects on health, environment and culture remain unanswered. The purpose of this paper is to present both the positive and negative effects of GE and GM products and to support a policy framework dealing with these issues.
Outline of Paper

Section 2 describes the uniqueness of GM technology by defining genetic modification and outlines the history of this technology. Section 3 discusses diffusion of the GE technology, the market structure, and the leading GM companies. Section 4 presents an extensive argument on the costs and benefits as well as the risks and controversies of Genetic Engineering. Section 5 is concerned with the policies and regulations of GM products in different countries. Section 6 discusses the socio-economic implications of the genetic engineering in agriculture. Section 7 presents several methodological approaches (including the Cost Benefit analysis) that are able to account for these socio-economic implications. Finally, this paper offers recommendations concerning the actions that can be taken by individuals, groups, and, especially, governments when considering genetic modification.
2. Genetic Modification and its Historical Outline

2. A Terms and Definitions.

The terms “Genetic engineering” (GE) and “Genetic Modification” (GM) are used interchangeably. Genetic Modification is the process of “manipulating genes, usually outside the organism’s reproductive process.” The isolation, manipulation, and introduction of DNA onto cells or model organisms are necessary parts of GM technology in order to express protein. The goal of such an introduction is to “impose” certain characteristics or attributes (physiologically or physically) to create a new protein or enzyme; for example, one that would produce crop tolerance to herbicides. Products that have been exposed to genetic modification are said to be “genetically modified,” “genetically engineered,” or “transgenic.” One application of genetically modified products is in the food industry. Food products derived from a genetically modified organism (an organism with altered genetic material) - plant, crop, animal or microbe such as yeast - are genetically modified foods. This alteration is achieved by using recombinant DNA technology – the “ability to combine DNA molecules from different sources into one molecule in a test tube” (Wikipedia). It is worth mentioning that this technique is different from conventional cross breeding or “mutagenesis.” These methods were used long before the discovery of DNA.

2. B Historical Outline

In the scientific world, very few inventions are “radical to the field.” In fact, most of them build on the knowledge obtained in the past, which makes the rapid progress of
science possible. Thus, knowledge obtained by one scientist can be used as a platform for the research of another scientist. The case of GM technology is no different. The process of scientific discovery in the related fields started several centuries ago. Darwin’s theory of evolution was published in 1859. In 1865, Gregor Mendel presented *Experiments in Plant Hybridization* to the scientific community. Mendel found the inheritance patterns of certain traits in the pea plant and showed that it was possible to describe them mathematically. The importance of Mendel’s work was not understood until the twentieth century, when his research served as a compass in the studies of similar problems. Mendel himself did not understand the nature of inheritance. It was in the year 1903 that chromosomes were discovered to be hereditary units. Two years later, the British biologist William Bateson introduced the term “genetics.” In 1910, it was found that genes reside on chromosomes. In 1918, the publication of Ronald Fisher on *Mendelian Inheritance* started a new era in biology and science in general. This modern evolutionary synthesis brought a connection between genes (the units of evolution) and selection (the mechanism of evolution).

In 1927, physical changes in genes are said to be “mutations.” (1). In the 30s and 40s, the scientific community obtained a great deal of knowledge about genes: their structure, functions, and applications. In 1953, James Watson and Francis Crick described the DNA structure as a “double helix.” Another very important discovery for genetic modification was made in 1970: the finding of restriction enzymes (enzymes that cut double-strand DNA), which enabled scientists to “cut and paste DNA.” The origins of genetic engineering itself started with the Nobel prize-winning discovery of DNA and the production of recombinant E.coli bacteria. This scientific advancement still plays an
important role in the genetic modification. In fact, the first useful application of recombinant DNA technology was the manipulation of E.coli to produce human insulin. All of these discoveries led to an era of genetic engineering and research in this sphere.
3. Development of the GM Technology and GM Food Market

3. A The Application of the GM Technology

The era of Genetic Modification brought about enormous commercial opportunities for the food and drug industries. The food and drug industries are the main markets where GM products are being distributed. Human insulin was the first Genetically Engineered drug, which was approved by the FDA in 1982. Yet another early application of GE was the human growth hormone. Perhaps the most successful application of GE technology is Genetically Modified Organisms (GMO). Genetically modified food has been on the market since the 1990s. Genetically modified soybeans, maize, and canola are basic sources for the principle ingredients of GM food. Tomato, called FlavSavr, was the first commercially grown GM food crop introduced by the company Calgene in 1992. The product was available on the market in 1994. Consumers evaluated it poorly because of its unpleasant flavor. The product was withdrawn from the market in 1997. However, it was a “perfect” tomato for canning purposes because of the improved content of solids.

Today the list of products that are “genetically modified” is very extensive: cotton, corn, sugar beet, wheat, tomato, potato, flax, squash, papaya, cantaloupe, soybean, rice, and canola are examples (The full list and description of these GM products can be found at www.cfsan.fda.gov), (CFSAN). Over 40 countries on six continents are commercially growing GM crops. The total surface area of land cultivated with GMO has increased by a factor of 30 (from 4.2 million acres to 128 million acres) between 1996 and 2001. In 2004, the area was 200 million acres, two thirds of which are in the USA (see Table 1,
Appendix 1). There are four countries that ‘share’ 99% of the land that is occupied by GM crops: USA – 68%, Argentina – 22%, Canada – 6%, and China – 3%. It is estimated that about 70% of products that are carried in American grocery stores contain GM ingredients. Seventy five percent of all processed foods contain GM ingredients. Bt corn, soybeans designed to tolerate herbicides and insecticides, and canola are the leading GM products. The USAD estimated that 38% of all corn and 80% of all soybeans planted in 2003 were genetically modified (Wikipedia).

Market opportunities for GM product are tremendous. Future applications include bananas, vaccines against infectious diseases, fruit and nut trees that yield earlier, fish that mature faster, etc. The interest in the research and development of GM products suggests that the market of these products will grow rapidly in the next decade. Nonetheless, at this time GM technology is still at the early stage of diffusion. There are several barriers that prevent it from diffusing more rapidly. The main barriers are the concerns of farmers, consumers, and environmental organizations and disagreements between different countries about utilization of GM products.


As stated, market opportunities for GM products are growing rapidly. As a result, many new firms are trying to enter this market. There are about 27 established companies in the territory of the US that commercially grow GM crops. The “Monsanto” company of the state of Missouri is by far the largest producer of GM products. The other four leaders are “Dow Agro Sciences” of Illinois, “Calgene” of California, “AgroEvo” of North Carolina, and “Dupont Agricultural Products” of Delaware.
The market for GM products can be characterized as containing a high degree of monopolistic power and there are several barriers that can prevent a newcomer from entering the industry. First of all, by the nature of the GE product, a firm will have to invest into research and development of the future product or buy GE seeds or foods from already established firms such as Monsanto. License and royalties used to obtain use of the technology increase firm’s fixed or sunk cost (depending on the nature of technology). Second, there are governmental regulations that prevent a company from starting production “on the spot” – prior testing has to be done on the safety of a new product. Third, there are negative attitudes of some consumers, farmers, and environmental organizations due to the lack of agreement in the scientific circles about the long-term effects of the GMOs on the environment and human health. Thus, a new company has to be able to find a firm ground in order to establish a profitable business. However, in the U.S. the absence of labeling and the lack of proper information in the U.S. media about GM products have left consumers uninformed about the potential consequences of genetic modification. For example, in a recent poll 70% of the Americans had never heard of Genetic Engineering or considered it as hybridization or cross-pollination. Nevertheless, in U.S. the GM industry is thriving. According to the National Center for Food and Agriculture Policy, GM crops created a net value increase of $1.5 billion to the food industry in 2001 (Kawar, 2003).

The U.S. market for Genetically Engineered products is peculiar. It has to be noted that currently the food market consists of organic, conventional (produced using pesticides and herbicides), and genetically altered products. Due to several factors, the market for GM products merged with the conventional food market. For instance, US
bio-engineered foods regulations do not distinguish between the conventional and genetically engineered foods. Thus, unique GM products are being placed on the market the same way as other products. Often the costs of growing GE crops are a lot smaller than the costs of growing conventional or organic crops. This is due to a genetic technology that “codifies” needed information into the plant and, thus, certain characteristics can be suppressed or magnified without extra cost (ex. plants with resistance or tolerance to insects). No specific labeling is ascribed for such plants or products that have some ingredients from them. This fact creates a challenge of tracing particular effects of the GM products on the food market itself. The same is true for attempts to measure the magnitude of the GM food market. However, knowledge that some markets (such as soybean, corn, and wheat) exhibit a very high degree of GM crops (from 70-90%) permits some industry analysis. For example, four-firm concentration ratios\(^1\) are presented in the Table 2.

**Table 2. Concentration Ratios of the Top Agricultural Firms, 2001.**

<table>
<thead>
<tr>
<th>Product</th>
<th>Concentration Ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn exports</td>
<td>Cargill-Continental Grain, ADM, Zen Noh - 81%</td>
</tr>
<tr>
<td>Soybean crushing</td>
<td>(ADM, Cargill, Bunge, AGP) 80%</td>
</tr>
<tr>
<td>Soybean exports</td>
<td>(Cargill-Continental Grain, ADM, Zen Noh) 65%</td>
</tr>
<tr>
<td>Flour milling</td>
<td>ADM/ConAgra/Cargill/General Mills/ 61%</td>
</tr>
</tbody>
</table>


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\(^{1}\) The inconsistency was noted for the agricultural industry CR4: only three firms are cited in the parentheses, when the rest of the source discusses four-firm concentration ratio.
The concentration ratios are comparatively high. In general, economists believe that a concentration ratio higher than 40% signifies an uncompetitive market (Gillian, T. W.). There are several processes that accompany concentration: horizontal integration (consolidation of ownership within one stage of the food system); vertical integration (following up the whole process from production to distribution); and global expansion. Companies can engage in formal or informal agreements to form alliances in order to achieve higher profits. Cargill and Monsanto formed a cluster in which Monsanto has been providing genetic material and seeds; Cargill has been involved in grain collection, processing, meat production and processing. Kroger, the largest supermarket chain in the US, is linked to this cluster through an agreement with Cargill. DuPont/ConAgra and Novartis (Syngenta)/ADM have similar ties (Heffernan et al., 1999). Most of the large players in the food market follow a strategy of diversification – they produce both Genetically Engineered and organic foods – that covers the entire market for consumer products. However, it can be risky for business to be able to appeal to different consumer groups, when some of the groups have negative attitudes towards conventional products and genetically modified foods and choose organics; and some might become distrustful of quality of the mainstay products as more and more organic foods are appearing on the shelves of the stores. For many companies the risk outweighed by the higher profits from the increased GE crop yields and lower prices of such crops.

As mentioned, vertical integration is quite common in the food industry. Companies that practice GE solely penetrate production and retail markets, forcing out conventional foods firms. Why is this the case, especially when the large food and agriculture firms are not, per se, the leading GE companies? The answer to this question lies in the heart of a
seed industry. This is where true concentration of GM technology starts. The idea is that Gene Kings like Monsanto, Dupont, Dow, and others cultivate GE seeds, patent them, and sell to the farmers all over the world. Thus, through the retailer chain, more and more GM products reach the consumer. In the USA, it is generally the case that if a certain product does not have a “Certified Organic” stamp, it is likely to have one or more GE ingredients (such as a soy component or GM bacteria). Table 3 presents the annual sales in the seed industry for the year 2004.

Table 3. World Top 11 Seed Corporations 2004 (Sales; US millions)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Corporation</th>
<th>Sales (US millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Monsanto (US) + Seminis pro forma</td>
<td>$2,803</td>
</tr>
<tr>
<td>2</td>
<td>Dupont/Pioneer (US)</td>
<td>$2,600</td>
</tr>
<tr>
<td>3</td>
<td>Syngenta (Switzerland)</td>
<td>$1,239</td>
</tr>
<tr>
<td>4</td>
<td>Groupe Limagrain (France)</td>
<td>$1,044</td>
</tr>
<tr>
<td>5</td>
<td>KWS AG (Germany)</td>
<td>$622</td>
</tr>
<tr>
<td>6</td>
<td>Land O’ Lakes (US)</td>
<td>$538</td>
</tr>
<tr>
<td>7</td>
<td>Sakata (Japan)</td>
<td>$416</td>
</tr>
<tr>
<td>8</td>
<td>Bayer Crop Science (Germany)</td>
<td>$387</td>
</tr>
<tr>
<td>9</td>
<td>Taikii (Japan)</td>
<td>$366</td>
</tr>
<tr>
<td>10</td>
<td>DLF-Trifolium (Denmark)</td>
<td>$320</td>
</tr>
<tr>
<td>11</td>
<td>Delta &amp; Pine Land (US)</td>
<td>$315</td>
</tr>
</tbody>
</table>


At the top of the list are three “Gene Giants” – Dupont, Monsanto, and Syngenta. According to Phillips McDouglas Agriservice, Bayer and Dow attained sales on the biotechnology market worth around $3,000 million in 2001 (Schmitt, 2002). The top ten firms accounted for aggregate seed revenues of $7,000 million dollars in 2002. This is approximately one third of the world commercial seed sales (ETC Group, 2005).

The concentration ratio for the largest four firms in the seed industry for 2004 is

\[ CR4 = 13.3\% + 12.4\% + 5.9\% + 5\% = 36.6 \] (Total worldwide seed market of approximately

\[ 2 \]

Four-firm concentration ratio is based on sales in million dollars for the year 2004.
US$21,000 million per annum). Thus, four companies control 36.6% of the world’s commercial seed market. Four companies control 49% of commercial soybean market. So-called “non-merger merges” are highly common in the seed industry. In April 2002, Dupont and Monsanto agreed to exchange their key patented agricultural technologies. This agreement gave both Gene Giants cross-licenses for maize, canola, soybean technologies, and also gene transformation technologies. Another trend among the leading Gene companies is a reduction in the amount of the conventional seeds and pesticides that they carry. According to the Chemical Market Reporter, crop protection chemicals and conventional seeds growth are declining at two percent, while GM seeds are growing at 16 percent rate (Doris de Guzman, 2003). However, the decrease in the chemicals for crops production does not signify that GE companies cut down on their usage. On the contrary, they created crops that genetically “depend” on company’s chemicals. Essentially, it represents a bundle and in some cases a tie-in (a particular example will be discussed in the Section 3.C.). A study done by Northwest Science and Environmental Policy Center concluded that over an eight-year period (1996-2003), planting the commercial GM crops increased pesticide use by about 50 million pounds (Benbrook, 2003). Thus, the amount of chemicals and seeds produced for conventional crops decreases while those for GE industry increases.

In general, the industry for GM products is using a research and development strategy to create an advantage over competitors to ensure future returns to their investment. Leading company in the seed industry – Dupont – released 43 new corn hybrids in the 2003, 28 of which are genetically modified. Syngenta allocated $170
million dollars to biotech research, which is 30% of its total research and development budget (Milmo, 2003).

Vertical integration is another very effective strategy of GE companies. As discussed, Cargill, Monsanto, and Kroger formed a cluster, where Monsanto has been involved in research and development and has been supplying Cargill Corporation with new technologies. Cargill is involved in grain and meat production and processing. Kroger, in turn, is a countrywide retailer that carries meat that has been supplied by Cargill. DuPont/ConAgra and Novartis (Syngenta)/ADM have a similar business arrangement. Companies also practice package sales, bundling and tie-ins. Dupont seed offers better interest rate on financing, depending on the choice of the farmer to buy approved chemicals. These are products from Syngenta, Bayer/Aventis, and Dow. These companies also practice bundling chemicals and other inputs with conventional seeds. Thus, GE companies form vertical agreements (some conduct research, others produce, and some distribute) and “share” sales amongst each other.

**Chemical-Based Farming**

The main industry-competitor is chemical-based farming. It uses pesticides to deal with weed and insect problems. Most non-GM farming is carried out this way. Proponents of GM technology claim that the use of chemicals is one of the disadvantages that genetic modification can successfully overcome, because it manages to create plants that are herbicide tolerant and insect resistant. However, GE companies do not mention that most of their GM seeds are designed to “work” with chemicals.

**Organic Farming**
Another alternative industry is organic or ecological farming. We emphasize that it implies not only the avoidance of chemicals, but it approaches farming holistically. It concerns itself with rotation, selection of tools, time of planting and cultivation, and internal drainage as ways of dealing with “weed problems.” Thus, organic farming tries to “avoid the problem” by working with existing synergies rather than finding the way to “solve” it. Organic farming is thought of as the most environment-friendly type of farming. However, there are many opponents of this technology that complain that it takes too much land to grow crops. Today, organic products are not big competitors for conventional and GM products. The amount of profit comprised from them is comparatively small. Although, the market for organic products is growing rapidly as more and more consumers discover the benefits of healthy and responsible living.

However, as it was noted before, most companies are trying to maximize their efforts in pleasing the consumers; whether they produce, retail, or produce and retail both GM and organic products.


It is known that “today, the top 10 seed companies control 30% of the global seed trade” (RAFI, 1998:13). Monsanto is definitely one of the companies, which has been aggressively trying to consolidate the market through formal and informal agreements. The company was not in a “first mover advantage,” position when it entered the GM market. However, it was able to gain a lot of the market power very fast. Since 1996, Monsanto has invested 8.4 billion dollars in building up agreements and buying out companies that have DNA codes databases, patents, procedures for cross-pollination, and access to food, seed, and pharmaceutical markets. Monsanto makes connections all over
the world. In particular, it is interested in the Brazilian soybean market (Brazil is the second largest soybean producer). The interest of the company is justified by the fact that Monsanto holds a monopoly position in all GM soy technologies.

In 1996, Monsanto and Dekalb Genetics signed a ten-year research and development agreement (Robertson, 1998: 325). This allows both companies to exchange the licenses for corn and soybean seeds. In 1997, Monsanto and Millennium Pharmaceuticals signed a 218 million dollars partnership. The goal of this agreement is for Millennium to transfer its technologies in genomics, gene sequencing, and bioinformatics to Monsanto (Marshall, 1997: 1334). In 1998, Monsanto bought Cargill Incorporated for 1.4 billion dollars. This purchase allowed Monsanto to have a leading role in production and research facilities in 24 countries and access to sale and distribution transactions of over 51 countries (Johnson, 1999:1). These are just few of the companies’ “super-deals.” However, the most interesting one was done in 1999 for 1.9 billion dollars with Delta and Pine Land Company. This firm had US patent #5723765 that controls plant gene expression. Among other “helpful” features, it patents the ability of a plant to self-terminate after one-time crop is gathered. Therefore, there is no second generation of seeds produced. The technology is called TPS (technology patent system). This amazing technology ensures a good crop for a farmer and annual profit for Monsanto. However, a farmer cannot save the seed for the next year. Monsanto addressed this issue in a press statement explaining that each farmer should respect the amount of research that was put into the development of this amazing product and should not try to save the seeds. Few companies were able to come up with a product like this that “keeps on giving.”
Another area where Monsanto affects the whole industry is the company’s chemical production. The firm was able to successfully develop a seed that actually reinforces sales of the Monsanto’s brand of a weed killer – Round Up. Round Up Ready gene trait tolerant to the company’s weed killer is now growing on more than 40 million hectares worldwide. Thus, Monsanto have created a perfect complement or a bundle: a trait and a weed-killer. Monsanto does not stop on what it’s already achieved, it will allocate 80 percent of its research and development budget on biotechnology (SeedQuest News, 2003).

All of the strategies described above signify a strong willingness of the company to concentrate the GE market and possibly establish dominance on it. To summarize Monsanto’s company makes large, diverse investments in research and development. In year 2002, its sales for the seed industry comprised $1.6 billion (second largest company on the market); agrochemical industry – $3.088 billion (third largest company) (Agro World, 2003); its division on the food and beverage processing industry Cargill Inc. sales were $21.5 billion dollars (seventh largest company on the market). In 2004, Cargill moved to a fifth position in the world; its sales for this year comprised $27,260 million dollars (Food Engineering, 2003).
4. A Genetic Modification versus Chemical-based and Organic Farming

GM technology has a lot of potential, but it carries certain risks as well. Recombinant DNA technology allows imposing certain characteristics on a given plant or organism. For example, a plant can develop herbicide tolerance and insect resistance. This is supposed to benefit the farmer by reducing production costs. It also has an indirect effect on the consumer by making the product “free of chemicals” (some, however, argue with this opinion). There is a reduction in greenhouse gas emissions from decreased fuel use. Also, GM farming reduces the need for plowing and improves conservation tillage. It was estimated that this reduction was equivalent to eliminating ten billion kilograms of carbon dioxide from the atmosphere in 2004.

However, these impressive improvements can advantage GM farming only when compared to chemical-based farming. Indeed, the first wave of biotechnology concentrated its research on how to deal with the issues of weed and insect control. The solution was to use herbicides and insecticides. In 1995, herbicides accounted for 64% of total biocide sales in the US, with corn and soybean sharing 65% of these. The use of insecticides increased by 20% between 1986 and 1995. In the past three decades, the number of insecticide treatments increased from one to six per acre. Consequently, farmers’ costs have grown tremendously. The cost of “seed plus chemicals” increased by 50% between 1975 and 1997 (Benbrook, 1996). The question arises: why is there a need for more chemicals? The answer is that traditional chemicals do not work any more. GM
technology offers the alternative. However, some scientists argue that genetic engineering not only does not solve the problem that chemical-based farming poses, but even worsens it. E. Ann Clark, Associate Professor in the Department of Plant Agriculture (University of Guelph, Ontario, Canada), confirms, “in addition to stimulating outbreaks of secondary pests, GE crops screen for and promote expansion of tolerant and resistant biotypes and demand ever higher and more targeted biocide use” (Clark, A. E.) Do GE crops reduce chemical use? The answer can be obtained from the information provided by the USDA (Table 4).

<table>
<thead>
<tr>
<th>GE versus non-GE crops (1997 only)</th>
<th>Acre treatment(^3) at 5% level significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insecticide use</td>
<td>Lower in one of one region for Bt corn (from 0.07 to 0.00)</td>
</tr>
<tr>
<td></td>
<td>Lower in two of three regions for target pests of Bt cotton</td>
</tr>
<tr>
<td>Herbicide use</td>
<td>Lower in zero of one region for HT corn</td>
</tr>
<tr>
<td></td>
<td>Lower in three of five regions for HT soy</td>
</tr>
<tr>
<td></td>
<td>Lower in one of two regions for HT cotton</td>
</tr>
</tbody>
</table>


According to the information in Table 4, in the year 1997 insecticide use for target pests was reduced in three out four regions for Bt corn and Bt cotton combined. In the same year, herbicide use for target pests for HT corn, HT soy, and HT cotton was reduced in four out of eight regions. However, for non-target pests, growing a GE crop (*Bt cotton*) increased insecticide use in one out of three regions and modestly increased the overall dependence on insecticides (Table 5).

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\(^3\) An acre treatment is the number of different pesticides applied per acre times the number of repeat applications
Table 5. Insecticide Use Patterns for Bt and non-Bt Cotton in Three Regions in 1997

<table>
<thead>
<tr>
<th>Bt target pests</th>
<th>All other pests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bt</td>
<td>Non Bt</td>
</tr>
<tr>
<td>Mississippi portal</td>
<td>0.54</td>
</tr>
<tr>
<td>Southern seaboard</td>
<td>0.31</td>
</tr>
<tr>
<td>Fruitful rim</td>
<td>0.63</td>
</tr>
<tr>
<td>Mean</td>
<td>0.49</td>
</tr>
<tr>
<td>Sum</td>
<td>For Bt cotton, 5.01 acre treatment; non-Bt cotton, 4.58 acre treatment</td>
</tr>
</tbody>
</table>


As it can be seen from Table 5, growing Bt cotton reduced insecticide use for Bt target pests (that is why Bt corn was created), but moderately increased total insecticide use by about 9% (5.01 versus 4.58 acre treatments). Thus, proponents of GM technology do not consider the fact that non-targeted species will multiply as the number of targeted species decreases, which in at the end will cause the application of more pesticides. Therefore, it is arguable that GE crops reduce the amount of biocides.

Organic farming, or any other ecologically based farming, should be considered before GM and chemical-based farming because of its sizable advantages. Opponents of organic farming claim that it does not give more yield than other types of farming, unless, there is a larger “base” – more land. And this, they say, can have potentially harmful effects on marginal land. However, striving for a large yield does not give an advantage to farmers, nor does it benefit consumers and the environment. For instance, Canadian
farmers are left with only 10% of value from what they grow. Thus, around 75% is going to the seed trade and chemical purchases. Moreover, the more yield there is, the more crops are in supply. Since farmers are on an inelastic market, they have to sell their crops for less, consequently getting less marginal profit. On the other hand, consumers are paying high prices due to processing, transportation, and retail costs. The actual product (wheat, corn, etc.) that they are receiving comprises the lowest proportion of their disposable income. On contrary, organic farming with its “smaller yields” would not lower the profit for farmers and rise the price for consumers. As it was discussed earlier, the environmental effects of GE and chemical-based farming are a lot worse than the effects of organic farming.

Proponents of GM technology argue that an ever-growing population needs more and more food; therefore, farming should seek to produce larger yields. Genetic engineering, they affirm, is the perfect answer to this. It “promises” to engineer plants that are able to withstand harsh environments and have long shelf lives. However, according to the United Nations Food and Agriculture Organization (UNFAO) report, the production of food can meet the global demand without GM crops in the year 2030 (Food and Agriculture Organization of the United Nations, 2000).

Another argument that is presented in favor of GM foods is that it will be able to eradicate poverty and malnutrition in Africa and other developing countries. However, the main problems causing hunger in those countries have a political nature (wars, poor land management, financial dependency on the IMF, large debts, etc.) and not of the technological sort. Also, there are economic implications: globalization and the free
markets attract big corporations and their investments to these countries. The consequences of this for the native population is very unpleasant: fishing communities are driven out of business, farmers are left without their “bread” and forced to find jobs in urban areas, even public goods like water are privatized (Wee, V. et al.). Thus, as we can see, poverty and hunger are not the foremost problems of technology of production. They are the problems with regulating the world income distribution, dealing with political powers, and simply acknowledging ideas such as human rights and equality. Therefore, the argument about the ability of GM technology to “save the world” from hunger and famine has to be reevaluated.

4. B Health Effects of Genetic Modification

The health effects of GMF are the greatest area of concern. Many scientists around the world confirm that there is a lot of uncertainty of the real effects of GM products on human health. They assert that a lot of research has to be done before GM technology is allowed to fully invade the market. Traceability of the effects of GM foods on human health is prevented because of the absence of proper segregation and labeling (the labeling policies will be extensively discussed in the Section 5.

Showa Denko Case

There is evidence of serious health effects of GM foods. In 1988, the company Showa Denko switched from its traditional way of producing an L-tryptophan supplement to a GE approach. The product was a staple in health food stores and was considered a safe treatment for insomnia – “the ingredient in warm milk that brings on sleepiness.”
The procedure was carried out in the following way: a “gene for I-tryptophan was spliced into bacterial DNA to synthesize a new production strain (Strain V). The bacteria were grown in fermentation vats, from which I-tryptophan was extracted and purified.” Since the product was considered “safe” for many years, consumers pursued their purchases of the new medicine. However, within a month ‘Strain V’ killed thirty seven people, 1535 people were permanently and severely disabled with “eosinophilia myalgia syndrome,” and five thousand were temporarily disabled. It was claimed that the product was 99.6% pure, but the cross contaminants (one being EBT) were enough to kill or disable a person. Although the tragedy occurred right after the company switched to the Strain V, the real cause is still unclear because Showa Denko destroyed all the evidence, including the strain, before the investigation team of the FDA arrived. Showa Denko made official claims that the cause of the accident was due to a reduction in the amount of activated carbon. However, the company’s lawyers justified that it happened before without undue effects (Boyens, 1999).

Food-born Illnesses

Another area of concern is the ever-increasing number of food-born illnesses since 1994 (the year of the appearance of GMF on the market). According to the report *Food-related illnesses and death in the United States*, released in 1999, food-borne diseases cause approximately 76 million illnesses, 325,000 hospitalizations and 5,000 deaths in the US each year (Mead et al., 1999). Known pathogens account for 19% percent of food-born illnesses. This means that unknown agents account for approximately 81% of food-born illnesses and hospitalizations and 64% of deaths. The number of food borne
illnesses more than doubled in the past decade (Council of Agriculture Science and Technology, 1994). In 1994, the figures were between 6.5 and 33 million illnesses per year. In terms of incidence, the increase is from 25 to 130 cases per thousand inhabitants in 1994, to 278 per thousand in 1999. What might cause such an increase?

A one-year Swedish study might bring some light on this issue. It took place between 1998 and 1999 in the Municipality of Uppsala of 186,000 inhabitants (Lindqvist et al., 2001). Five hundred and fifteen cases were documented and 268 incidents were recorded (twenty eight incidents per thousand citizens). This is comparable with the US food-born illnesses records for 1994. Consequently, this means that the incidents in the US increased tenfold in 1999 compared to 1994 and tenfold compared to that in Sweden. Some other aspects of the Swedish study are comparable to those of the US. The etiological agent was unknown in 79% of the cases in Sweden (81% in the US). The difference appeared in terms of known etiological agents. In Sweden, “bacteria were found to cause 10% of the incidents and 25% of the documented cases, compared with 13% of the cases in the US. Viruses, on the other hand, caused only 9% of both the incidents and documented cases in Sweden compared with 80% of cases in the US.”

The Swedish study suggests that incidents of the food-born illnesses are comparable to those of the US in 1994, which is not strange because both countries had similar food hygiene. However, the results are vastly different for 1999. The United States experienced an increase in food-born illnesses of up to ten fold. This fact has to be thoroughly researched. Notably, the amount of GM food on the American market grew tremendously since 1994. The proponents of GE technology insist that it does not bring
any harm but the “health authorities should be on the lookout for new viruses and bacteria that could evolve by the horizontal transfer and recombination of viral and bacterial genes in the genetically engineered crops” (Ryan et al., 2003).

**Antibiotic Resistance**

Another area of concern with GM products is antibiotic resistance. In order to indicate that organism was successfully engineered, genetic engineers include antibiotic resistance genes as ‘posts’ nearly in every genetic engineered organism. In the May 1999 report on GMF, the British Medical Association stated, “There should be a ban on the use of antibiotic resistance marker genes in GM food, as the risk to human health from antibiotic resistance developing in microorganisms is one of the major public health threats that will be faced in the 21st century” (British Medical Association, 1999). The American Medical Association expressed the same concern.

**New Allergies**

Yet another problem is that GM products might bring a new wave of allergies and toxins as they introduce “foreign” elements to the human body. Also, GE technology can create danger for which it will be difficult to test. Inserted into the target organism, transgenes can affect (e.g. alter) traits, whether they were intended to be altered or not. Notably, this is not considered in the safety protocols used in the US and Canada (Benbrook, 1999).
Laboratory Test Results

The most recent study on the effects of GM soy on rats in the laboratory conditions was done by the Institute of Higher Nervous activity and Neurophysiology, Russian Academy of Science, in 2005 (Ermakova, 2005). The goal of the experiment was to evaluate the influence of the GM Roundup Ready (RR-soy with the transgene CP4 EPSPS; 40.3.2 line, Monsanto) on the Wistar rats. Female group of rats was divided into three groups: those who were fed with laboratory chow plus RR-soy flour (5 to 7 grams/rat/day) before and during mating, during pregnancy and lactation; those who were fed with chow plus the same amounts of the traditional soy variety (arcon SJ 91-330, ADM; which is similar in nutritional value and composition to the RR-soy); and those that were given just the laboratory chow without any supplementation (the control group). Physiological conditions, the behavior, and the mortality were monitored, recorded, and analyzed all through the experiment. From the 15 females in the experiment, eleven gave birth to a total of 132 pups. In the ‘Traditional’ group three out of six females gave birth to 33 rat pups. In the GM group four out of six females brought forth 45 pups. In the control group the number of newborn pups was 44.

The results of the experiment were quite devastating. By the end of the third week of lactation, twenty-five out of forty five pups in the GM-group died. Only three pups out of thirty-three in the ‘Traditional’ group have died (Table 6).
Table 6. Mortality of Rat Pups by the End of the 3rd Week of Lactation

<table>
<thead>
<tr>
<th>Groups</th>
<th>Number of pups born</th>
<th>Number of dead pups</th>
<th>Dead pups/total born (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive control</td>
<td>44</td>
<td>3 (p=0.000118)⁴</td>
<td>6.8%</td>
</tr>
<tr>
<td>Trad. Soya</td>
<td>33</td>
<td>3 (p=0.000103)⁴</td>
<td>9%</td>
</tr>
<tr>
<td>GM-soy</td>
<td>45</td>
<td>25</td>
<td>55.6%</td>
</tr>
</tbody>
</table>


Every four of the females in the GM group had from 46 to 64 percent of their litter dead by the end of the third week of lactation (see Table 7, Appendix 2). Considerable differences were noted in the weights of GM-fed pups compared to the other two groups (RR-soy group had pups considerably smaller that those of other groups). The difference in absolute weights is especially pronounced for livers, kidneys, and hearts of the GM-fed rats. The conductors of the experiments concluded that there are two possible explanations for such negative effects of the GM soya. First, the effects can be due to the insertion of the foreign genes and the following transformation and penetration into the cells of the fetus. Also, it can be attributed to “the instability of gene constructs” for GM-soy (Windels et al., 2001). Second, high mortality can be attributed to the accretion of the residues from the Roundup Ready in the soy. Scientists refuted the second explanation due to the fact that no mortality was observed for mothers and survived pups, which were continuously fed with the GM soy. Thus, the negative effects were found to be due to the first reason.

⁴ Compared to the GM-soy flour supplemented group

⁴ Identical to the previous footnote
These are alarming findings and conclusions. Since, on the one hand, the size of the GM market is quite large (and still growing) and, on the other hand, there is no adequate information for consumers, scientific society has to take a step and conduct a series of independent researches. Moreover, if more studies of the sort will come up with the same results, there will be not only large economic impacts but also social, environmental, and health-related.

4. C Environmental Effects of Genetic Modification

Concerns about Genetic Modification are not limited to health issues. There are also environmental concerns. Some of them were discussed at the beginning of the section 4 of the present paper (Tables 4 and 5). Others include soil and wildlife issues.

The Max Planck Institute for Soil Microbiology in Germany conducted research on genetically modified potatoes (Lukow et al., 2000). The findings include the fact that these potatoes change bacterial communities in the soil. These results indicate the strong need for further investigation of the long-term consequences of such changes; especially considering the fact that even smallest changes in microbial ecology can have devastating long-term effects on soil fertility, the availability of nutrients, and even on the promotion of pathogens such as nematodes, fungi, and harmful bacteria.

Also, biotechnology seems to be “against” biodiversity. It tries to deal with weed and insect problems by creating plants resistant to them. However, GM is not concerned with the side effects - the extinction of certain types of grass and insects. It is well known that there are food chains in nature and by reducing species GE affects wildlife in
general. The study on the extinction of certain types of field birds in England that was presented in 2002 to the Royal Society is one such case (The Royal Society, 2002).

One of the serious concerns that genetic modification caused in the scientific and agricultural circuits is the question of coexistence. Is it possible for GM and non-GM crops to exist and do not diminish the vital space and development of each other? Several concerns exist in regards to this question. First one is cross-contamination of pollen from GE plants to non-GE plants. This concern is very viable as of today. Hundreds of cases were registered when non-GM crop was found to have traces of their GM counterparts. Moreover, cross-contamination can lead to creation of super-weeds and thus will reduce the variety of non-targeted, area-based weeds. Second type of concern is GM seed dispersal during transportation, which basically leads to the same consequences as a first one. Third, almost all agricultural systems that grow both GM and non-GM crops do not have a segregate system of production and utilization of those crops. Thus, admixture of the residue seeds occurs during the sifting and sorting process of these two types of crops. Fourth concern is the fast evolution of resistance of insect pests such as Lepidoptera to Bt. Fifth, is “accumulation of the insecticidal Bt toxin, which remains active in the soil after the crop is plowed under and binds tightly to clays and humic acids” (Altieri, 2005).

Sixth, Unexpected effects on non-target herbivorous insects (e.g. monarch butterflies) through deposition of transgenic pollen on foliage of surrounding wild vegetation (Losey et al., 1999). Seventh concern is gene transfer that can lead to the creation of the new pathogenic organisms. All listed above concerns put strong doubt on the possibility of coexistence between GM and non-GM crops.
GE crops affect both conventional and organic agriculture. In fact, the latter suffers from both conventional (since it does not recognize the use of pesticides and herbicides) and GM agriculture (since uses only natural or organic ways of selection, cultivation, and production). Above ethical and economical there are agro-ecological basis of incompatibility between organic and GM systems of agriculture (see Table 9).

### Table 9. Characteristics of Organic Farming and Genetically Modified Based Agriculture

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Biotech</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum dependency</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Labor requirements</td>
<td>Low, hired</td>
<td>Medium, family or hired</td>
</tr>
<tr>
<td>Management intensity</td>
<td>High</td>
<td>Low-medium</td>
</tr>
<tr>
<td>Intensity of tillage</td>
<td>High except in no till systems</td>
<td>Low (no till w/o herbicides) to medium</td>
</tr>
<tr>
<td>Plant diversity</td>
<td>Low</td>
<td>Medium to high</td>
</tr>
<tr>
<td>Crop varieties</td>
<td>Genetically Modified, homogeneous, one variety over large areas</td>
<td>Hybrid or open pollinated, variety mixture</td>
</tr>
<tr>
<td>Source of seeds</td>
<td>Multinational corporations, all purchased, patented</td>
<td>Purchased form small seed companies, some saved</td>
</tr>
<tr>
<td>Integration of crop and livestock</td>
<td>None</td>
<td>Little (use of manure) to crop-livestock mixture</td>
</tr>
<tr>
<td>Insect pests</td>
<td>Very unpredictable</td>
<td>Unpredictable</td>
</tr>
<tr>
<td>Insect management</td>
<td>Insect-resistant crops</td>
<td>Integrated pest management, bio-pesticides, bio-control, habitat management</td>
</tr>
<tr>
<td>Weed management</td>
<td>Herbicide-resistant crops, chemical, tillage</td>
<td>Cultural control, rotations</td>
</tr>
<tr>
<td>Disease management</td>
<td>Chemical, vertical resistance</td>
<td>Antagonists, horizontal resistance, multiline cultivars</td>
</tr>
<tr>
<td>Plant nutrition</td>
<td>Chemical, fertilizers applied in pulses, open system</td>
<td>Microbial bio-fertilizers, organic fertilizers, semi-open system</td>
</tr>
<tr>
<td>Water management</td>
<td>Large scale irrigation</td>
<td>Sprinkler and drip irrigation, water-saving systems</td>
</tr>
</tbody>
</table>

4. D Social Problems

Together with health and environmental problems, there are, also, social problems. Some scientists emphasize the fact that research on GM products is strictly commercially supported. Large corporations are the leading institutions that support research in the GE sphere, expecting positive results in return. Also, most of the graduate programs in agriculture suggest studying mostly molecular genetics and related disciplines. Research and studies on “conventional agriculture” are not supported by the departments and do not get a lot of financial help from private companies or the government. This raises the question of scientific integrity and the reliability of GE and GM research (especially in the USA) (Clark, A. E.).

In spite of the controversies about GM technology, there are parties that benefit from genetic engineering. These are the government and companies that supply GM products. There is an obvious reason why corporations benefit - profit. On the other hand, the position of the government is not all that clear. Perhaps, it is motivated by the benefits from international trade, ideas about “feeding the world,” and a desire to bring benefits to domestic farmers, although, it is not always clear who benefits from trade in GM products. Moreover, there is little public evidence of existence of societal benefits from GM products to date. This can be based on the following: disregarding health and environmental concerns and despite the fact that GM allows to reduce production costs, increase agricultural productivity, and eventually increase the amount of the food supply non of these benefits were reflected in the price of the goods for consumers. First of all, there was never a distinction between the conventional products and the GE products.
Thus, the benefit of a “cheaper” technology was hidden from the consumers. Thus, they are still paying the same prices for the conventional and newly introduced GM products. Only proper labeling of the GM products and consequent reduction in prices of these goods are able to determine societal benefits.
5. Global Overlook of Policies on GM Products

Most countries consider two important policy approaches for addressing issues surrounding GM foods. One of the areas includes the standards for regulating and testing for food safety. The other encompasses labeling policies and the traceability of GM products. The approach for dealing with these issues is different in every country. The United States, for instance, does not require labeling of GM products. The regulation of safety and testing of GM as well as non-GM foods is under the jurisdiction of the Food and Drug Administration (FDA). The FDA created a special service – the Biotech Regulatory Service (BRS) – that regulates field and product testing, movements, and the importing of GMOs. Their reports are now publicly available on the BRS web site (Biotech Regulatory Service). Although GM foods do not require labeling, prior testing is an essential part of the procedure before the product is put into the market. Companies must submit documentation on the safety of their products to FDA and then wait for approval. The companies themselves test GM products according to the “FDA Statement of Policy: Foods Derived from New Plant Varieties.” This raises a question of accuracy of such testing. Proponents of such a policy argue that the results of testing are closely monitored; therefore, it is in the best interest of the companies to make sure that their products are safe.

The second area of the policies for GM products is labeling. According to Section 403(i) of the Federal Food, Drug, and Cosmetic Act, a producer is required to reveal on a
label, “all facts that are material with respect to consequences which may result from use.” This suggests that if the food derived from a new plant variety differs from its counterpart in safety or usage, then it should be labeled accordingly. But most GE foods do not require labeling, because the FDA does not consider the method of production of the new plant variety to be a “material fact”. The regulation of the crops engineered with pesticide protein becomes responsibility of the EPA. Despite this kind of policy, American consumers do not seem to be against GM foods; rather they call upon the authorities to present more thorough research on products safety.

On the other hand, EU consumers have a less liberal idea about Genetically Modified food. They require strict labeling and segregation of these foods on the market. Since April of 1998 till the end of 2002, the EU banned all GM foods (GMO Compass, 2006). After that, it had a policy to label all of the GE crops if they contain more than 0.5% of GM ingredients. In 2004, the EU developed a new set of rules for the traceability and labeling of GMFs. It requires labeling of highly refined products (oil and corn syrup) produced from GM components, even though the recombinant DNA or protein cannot be traced. However, labeling rules do not apply to products of microbial genetic engineering; thus, GM cheese does not require labeling. On July 13, 2006, the European Commission announced its current ban of GM crops illegal and is going to come up with a new set of regulations for labeling and traceability of GE imports. Environmental groups accord this move of the UC with the informal threat of the US to the WTO about unfair trade. As for today, the European Commission admitted a range of GM foods and crops despite having serious concerns about their safety for human consumption and environment. The reports released by the EC stated, “there simply is no way of
ascertaining whether the introduction of GM products has had any other effect on human health,” and, “no unique, absolute, scientific cut off threshold available to decide whether a GM products safe or not” (Daily Telegraph, 2006).

Japan maintains labeling of the GM products by the European standard. In Canada, labeling is not currently required. China is currently the largest producer of GM cotton. However, other GE crops such as tomatoes, pimentos, species of the morning glory and rice are grown in China. In March 2002, China presented new biosafety rules that demand strict testing and labeling of GM products. Currently, many Chinese institutions are working on developing and testing GE products.

Developing countries of the African, Asian, and Pacific regions have become more receptive to GE technology. Agricultural officials from these countries take training programs on GMO at the American Agriculture Department. At the same time, the US industry groups provide financial and technical support of GE research to the developing nations.
6. Integrating Socio-Economic Factors into Bio-Safety Decisions in the Agricultural Sector

Agriculture is a vital sector in many country’s economies. It is especially applicable in developing countries, where the agricultural sector is responsible for a large percentage of income and number of jobs. Thus, biotechnology has the potential to provide better living and sustainable growth in these countries. Unfortunately, the process of implementation of the biotechnology is a multi-faceted process and, thus, it affects not only secluded groups of people but also society as a whole. Because of its potential risks reliance on GM foods has to be evaluated from many perspectives. The interests of a wider range of groups and entities should be considered along with those of the consumers and producers of the GE products. In this paper, we discussed possible health, environmental, and social costs and benefits of genetic engineering. This section concentrates on the socio-economic implications of the biotechnology. It elaborates on such issues as distribution of wealth, involvement of the public research and development into biotechnology, labor markets, global markets, competition, organic agriculture, intellectual property rights, and public opinion, religious, and cultural concerns.

6. A Distribution of Wealth

Distribution of wealth is one of the factors that has to be considered in the light of the GE technology. One of the most vital questions of today is finding ways to alleviate
poverty. There are two approaches of doing so; the first is to increase food production. The second is to increase per capita incomes and thus enabling people to buy more goods. Biotechnology seems to address both approaches (Royal Society of London, etc., 2000). Economic studies during this past decade of GE implementation show that such technology indeed increased wealth significantly worldwide. For instance, Runge and Ryan in their 2004 study found that during the period of 2003-2004, the total value of the transgenic crops planted in five leading “GM countries” was forty four billion US dollars. The Australian Bureau of Agriculture and Resource Economics estimated that GE crop implementation during the next ten years would generate 210.3 billion aggregate annual GNP increase worldwide. The numbers are impressive, but the question rises of who is the primary receiver of that wealth? Is it poor and needy? Concerns exist that benefactors are going to be farmers in the developed countries and not in the developing; big corporations involved in design of the GM crops and not the farmers and consumers; and within the country it will be large farmers benefiting more than small farmers.

The concern that biotechnology benefits richer farmers and passes by poorer is based on the variety of traits that are currently in use. Most of them provide pesticide tolerance and herbicide resistance. Although they are beneficial to some (richer farmers), crops with these traits do not address the needs of the farmers in poor countries (such as heat resistance, water retention, drought and saline soils resistance, and enhanced nutrition). In 1999, a study by Falck-Zepeda et al. was done for Roundup Ready soybeans concluding that the benefit breakdown between GE companies, farmers, and consumers is heavily leaning on the side of the companies and farmers. Thus, 48 percent of the wealth created by the adoption of that crop was received by the US farmers,
Monsanto received 22 percent, seed companies received 9 percent, non-US consumers received 13 percent, and US consumers benefited 8 percent. The data for a third concern (large farmers versus small farmers) appears to vary amongst different countries. A recent study in China found that small farmers received a larger increase in yields than large-scale farmers. However, this was not true for the US. In fact, in the US GM crops often don’t yield as much as non-GM crops, and in some cases profits even declined (Femandez-Cornejo et al., 2002 and Duffy, 2001).

6. B Public Sector Research and Development

The lack of public sector research and development is another area of concern when looking at the biotechnology. The prevailing majority of the research for the development of the GE crops is currently conducted through the private sector. Some analysts site it as a glaring failure of the public institution to produce unbiased results. They argue that “positive” conclusions of such private studies are tailored for specific requirements of the interested party (usually the producer of the GM crops or seeds). They also site the fact that leading GE companies tend not to collaborate with the research institutions; they simply buy them out (see sections 3. B. and 3. C. of this paper). Moreover, the absence of the public research and therefore public ownership created a favorable environment for greater concentration of market power and formation of the monopolies (e.g. Monsanto in the US). The example of China had shown that these problems could be possibly avoided by involving public research sector and development. The Chinese Academy of Agricultural Science had introduced a home-developed sort of Bt cotton (currently Monsanto corporation offers comparable type of
crop). No studies were conducted to evaluate the effects of the presence of the publicly produced GM crop on the distribution of benefits. However, it is quite clear that this kind of competition would not allow for Monsanto to monopolize the market and possibly reduce the seed prices for farmers (Eaton et al., 2003). Thus, a strong recommendation can be made for inclusion of the public sector research and development into overall development process of the new GE crops.

6. C Labor Markets

The development of the GM crops can affect labor demand. It can both harm and help in solving some of the labor issues globally. For instance, in places such as some parts of Africa where diseases wipe out or reduce the work-years of most of the working population, GM crops can solve the problem of undersupply (Nuffield Council, 2004). Biotechnology would be useful for growers who are trying to cut down on labor demand (e.g. insect resistant crops supposedly reduce the labor required to spray pests against insects). However, in Asia where the level of mechanization is low and the amount of working population is high, the implementation of the GE laborsaving crops can be devastating. It can ruin the livelihoods of thousands of people. The effect of the increase in the amount of these crops should not be discounted for the labor market in general. Another recommendation is to conduct studies targeted on this issue.

6. D Global Markets

Global markets and trade patterns is another area of socio-economic concern regarding biotechnology. Attitudes, preferences, and tastes of the consumers define
which crops are imported and which are not. Thus, the benefits or profitability from a certain GM crop depends on the level of adoption to the whole idea of biotechnology. A study conducted by Anderson et al. in 2001, concluded that trade patterns (e.g. open trade vs. a ban on certain imports) define how many benefits a country will enjoy from adopting GM crops given the trade policies of its trading partners (Anderson et al., 2001). Specifically, if one of the trade partners refuses to import GM products on the basis of the consumer preference, a country-producer of such a product will encounter trade loss (e.g. US and European Union). Disregarding the health and environmental concerns, according to Anderson’s model overall benefits can increase if trade partners engage in GM crops production or importation. For instance, consumers can benefit from the reduction in prices; however, farmers may lose their profits due to the same factor.

The Anderson et al. study also concluded that countries that adopt a strategy of diverse production (e.g. GM products and non-GM products) will have an advantage in international trade. In order to lead this kind of strategy, a country would have to establish an effective system of segregation – labeling and separate production of GM and non-GM products. One of the downfalls will be an increase in the prices consumers pay. It was estimated that for Canada and the US, the production cost increase can be anywhere from fifteen to fifty percent and retail prices can increase by nine to ten percent (Paarlberg, 2002). Based on this information, a recommendation can be made for the governments to obtain relevant information on crops produced domestically, to collect information on their GM match produced abroad, to define the direction of exports of such crops and the consumer attitudes toward GM products on these markets. Lack of such information can create unfavorable trade conditions for the whole industry. Thus, in
2004, several European companies discovered that their suppliers from Thailand were illegally growing GM papaya. Some NGO’s, including Greenpeace, blamed the “leakage” of seeds on to the Department of Agriculture research station in Thailand. The seeds were not destined for commercial planting. After investigation, the government declared that it would destroy all the papaya trees that were contaminated. Nevertheless, EU companies stopped all imports of all canned fruit from Thailand in fear of contamination from GM papaya. Evidently, governments should take steps in clarifying trade policies on GM products, and, since a favorable degree of certainty is still not achieved, press the global communities for a distinct segregation and labeling of such products.

6. E Competition

One of the other socio-economic factors that have to be considered is competition. Rising competition on the agricultural markets is especially a characteristic of the developing countries. Some of them were among the first pioneers to adopt GM technology (e.g. Philippines); however, some were not but felt pressure to do so based on their perception of increasing global demand for the GM technology. In the end, these countries were afraid of being in economic disadvantage before their neighbors. In 2004, the Prime Minister of Thailand suggested lifting the ban on growing GMOs. He believed that failure to do so would mean that Thailand would “miss this scientific train and lose out in the world” (Thailand May Overtake, 2004). However, the Cabinet did not support the Minister’s thinking.
Research and development and introduction of the new GM traits that can adapt the crop to certain climatic conditions may cause major shifts in the world’s markets. Thus, markets that are historically responsible for production of cinnamon and coconut milk (mostly produced in the developing Asian countries) may lose their competitive advantage since their counterparts in the developed world will be able to produce these goods domestically. The same is for reverse products – crops that were produced only in developed parts of the world now can be produced in the developing nations. The estimation of such shifts will present an enormous challenge for economic analysts. The government of each country should consider the costs and benefits of these changes. Moreover, the importance of public research and development can be called in help.

6. F Organic Agriculture

Organic agriculture is another area of socio-economic concern. It is widely known that this production system excludes the traditional way of farming and the GM technology. The rapid rate of growth of the GM industry presents a huge challenge for the sustainable development of the organic industry. “Contamination” and the irreversible mix of GM crops with organics and conventional crops is today’s biggest challenge. It not only leads the organic farmers to enormous losses but also destroys the consumers’ confidence in the products they buy, recognizing the fact that the regulations concerning the cases of contamination are being treated differently in different countries. According to the USDA regulations, as of 2000 organic farmers do not necessarily lose their license if their products are found to have GMOs mixed with their organic produce.

Contamination of the organic crops by their GM counterparts is a growing problem that
happens mainly through cross-pollination. For instance, Terra Prima, organic company from Wisconsin, encountered losses due to the recall of the 87,000 bags of tortilla chips that were found to have GM corn. As of today, the coexistence between GM and organic farming is highly problematic (more careful discussion was conducted in Section 4.C.). The possibility of the pest resistance to the Bt toxin (natural organic pesticide) is another area of concern for organic farmers. Pest resistance might occur due to the high presence of this toxin in GE Bt crops (Altieri, 1999).

6. G Intellectual Property Rights

Another socio-economic factor to be considered with regard to GM technology is the question of intellectual property rights (IPRs). In some developed countries, which are leaders of the GM production, patenting is widely applied as a practice of protecting the developer IPRs. This often implies that anybody on the territory of this country wishing to use that technology has to pay a “technology fee” and sign a contract, stating that no attempts will be made to save, replant, or sell the seed. Companies justify this practice by the fact that the fee goes into covering the R&D costs. This practice might jeopardize a historical tradition of the farming community, where seeds are saved, selected, and shared amongst the farmers of the community. It was the primary source of innovation and preservation of seeds and new types of crops for centuries. In many farming communities, it is also a way of reducing the production costs. The prevalence of the GM technology is likely to stop this practice and make farmers more and more dependant on big seed corporations (e.g. Monsanto, Syngenta, Dow, etc.). Thus, farmers will be forced to buy new seeds every year. This will raise their production costs.
considerably. Moreover, in order to insure that no seeds are saved GM companies came
up with the Genetic Use Restriction Technologies (GURTs). Seeds obtained through this
technology produce sterile generation. That is why it is mostly known by the name
“terminator technology.” In some case a certain chemical can activate sterile offspring.
This further suggests that the company-innovator decreases its cost (no need for a seed
turnover) and increases the costs for the farmers (price of the initial seed plus the price
for the activating chemical). However, “terminator technology” is still an object of wide
discussion.

Due to the fact that the regulations for the IPRs differ from country to country, the
amount of use of the GM seeds varies also. For instance, in some countries, farmers were
sued for patent violation. Most developing countries do not have patent regulations for
GM products; thus, GE-giants do not trade with those countries or charge royalties in
another manner. One of such ways is to impose a shipment fee on GM products from the
country-producer without patent protection to a country that has it (e.g. Argentina and the
US). Strict IPRs may also decrease the level of independent research due to the fact that
scientists would have to collaborate with owners of the technology for the “use” of their
product. The absence of the patent regulation may also cause some scientists to decline
from the research in such countries (applicable to the most developing countries). Thus,
the needs of these countries in the field of biotechnology will not be addressed.
Governments of the individual countries have to consider what are the long-term effects
of the patent law implementation.
6. Public Opinion

Another social factor that plays an important role in understanding the significance of GM technology is public opinion. As previously stated, a strong argument for the GM technology is its claimed ability to “feed the world” and alleviate poverty. However, as it was also noticed earlier, the entire world population can be fed with a balanced diet as of today and for the next thirty years without interference of the GM technology (Pew Initiative, 2001). The real causes of hunger are inequality of income distribution, poor governance, poverty, and accessibility. In addition, the public perception of the GMOs can be biased due to the distrust of its own government and its ability to protect health of its citizens (example of EU).

6. I. Culture, Religion, and Ethics

Some of the least discussed but nonetheless extremely important socio-economic factors are the cultural, religious, and ethical implications regarding GM technology. Integrity or autonomy is one of the ethical considerations. It stresses the right and the ability of an individual to be informed and make choices based on that information. In the USA and most countries in the world, such a choice was not given to the consumers. As of today, there is still now adequate segregation and labeling of the GM products. Also, farmers who do not want to apply biotechnology to their production process should be ensured that they will be able to do so (e.g., problems of contamination and pest resistance). The farmers who want to embrace GM technology should be given a right to do so; however, the public should be assured that their GM products are safe for the environment and human health.
Another ethical principle to consider with respect to GMOs is the utilitarian approach. It uses the cost and benefit calculations in order to determine the direction of actions that would bring the most good to the most number of people (Purchase, 2002). On this basis supporters of the GM technology cite the fact that the benefits of “feeding the hungry” outweighs all the risks associated with it. On the other hand, opponents of the biotechnology argue that “playing with nature” at the gene level is unacceptable regardless of the possible benefits. Moreover, they argue that ecosystems and species have intrinsic value and should be protected at their initial state (Myhr, 2000). Many would argue that humans have been changing nature throughout history and thus there is no need to impose restrictions on GM technology at this time. However, the change that is about to happen due to the GM technology is very radical; in a sense, not only the world will never be the same, it might become a place that is foreign to humanity itself.

The cultural implications of genetic engineering, or a specific GMO, became an ongoing issue in the recent years. It should be recognized that for some cultures the adoption of GE might be unacceptable or only partially acceptable. For instance, in some communities, a certain level of biological diversity that is important to their culture can be ruined due to the introduction of the GE technology (e.g. GM maize in Mexico). These effects have to be counted when evaluating costs and benefits of the GE.

The religious concern is another issue rising from the development of the genetic engineering. Some argue that the alteration of the life form on such a level and then patenting it (claiming the life-ownership) is blasphemy (Warner, 2001). Moreover, many religions in the world (Christianity, Hinduism, Islam, Judaism) practice certain dietary
restrictions. Appearance of the GM products in the food chain (especially without segregation and labeling) can make these practices impossible and thus, will undermine religious believes of millions of people.

The enormous variety of ethical issues, cultural believes, and religions does not allow for the development of unified approach of accessing benefits and costs of the genetic engineering. Different countries and different cases will take diverse directions in evaluating genetic engineering. However, an independent recommendation for specific government is not to discount ethical, cultural, and religious factors when considering the adoption of the GE technology. Recommendations can be also made to the public: social dialog, extensive discussions with various groups present, and constant exchange of information should take place. On the basis of the discussion above and independent discoveries of the author, assessment of the methodological approach for evaluating impacts of the genetic engineering will be introduced in the next section.
7. Types and Approaches to Research Methodology. Assessment of the Cost Benefit Analysis for the GM Products

The integration of socio-economic factors into bio-safety decisions is by no means an easy task. At the present stage, two steps are necessary: first, research in the social science field is vital in order to identify and clarify socio-economic issues relevant to biotechnology in different national contexts and recognizing actual effects of the GMOs implementation on this particular environments; second, regulatory processes have to be applied in order to address those socio-economic issues. Today, the decision of introduction and adoption of a certain GM crop lies in the hands of the producers and the policy-makers. The voices of farmers, consumers, and public in general are silenced. That is why the emergence of a holistic methodological approach of assessing effects of the GM products is so important. It has to be noted that any methodology has its limitations. That is why the choice of the methodology should be done on a country-by-country or even a case-by-case basis. We will list few available methodologies and then develop one of them.

**Economic Modeling**

Economic modeling is one of the approaches that can be taken. The main goal of it is to predict the economic effects of a certain policy. However, more targeted questions can be answered such as which country will lose or benefit economically from the
adoption of GE products. Another useful tool can be a social impact assessment. This methodology is one to use when environmental concerns of adopting the GE technology is high. Thus, social impact assessment includes the environmental factors into its analysis. SIA can estimate the likelihood and the intensity of the potential impact of biotechnology, specifically, its effects on certain social groups. Both the advantage and disadvantage of this method is use of the quantitative and qualitative data. The latter is argued to have some subjectivity. However, it is still a very useful tool, especially in the cases where environmental impact evaluation is needed. For instance, it can answer the question on equity and thus provide a useful basis for the decision-making process.

**Sustainable Livelihood Framework**

Yet another method of socio-economic analysis is Sustainable Livelihood Framework developed by the UK’s department for International Development. The main tools of this method are: surveys, focus groups, interviews, household case studies, and secondary data. It uses all the data collected to track the connections between the household, community, and regional levels for better understanding of the true underlying problems. This type of research can successfully address some of the socio-economic factors that were discussed in the previous section (e.g. distribution of wealth and benefits) in relation to the technology of genetic modification.

**Systemic Relevance Assessment**

One of the other comparatively new methods of socio-economic analysis is the “Systemic relevance assessment.” It is said to be useful in identifying the relevance of a
certain GM crop. The evaluation is conducted on two levels: first, measuring the ability of the GM crop to address specific agricultural problems; second, measuring the ability of the crop to address needs of the farmers and fit within the general public’s goals. This method also has advantage of cross-dependency analysis (ex, between farmers and producers). Thus, this method shifts focus from the innovation itself to a specific problem that this GM crop can address or solve in the context of a specific community.

**Priority Setting through Participatory Research**

Yet another methodological approach is Priority-Setting through participatory research. This method in a sense is very unique. It concentrates on targeting and developing new GM products for alleviation of poverty. Apart from the method before, farmers are given the privilege to choose and select specific seeds (thus preserving a century-long tradition of seed-selection by farmers). Participatory research stresses the importance of including all of those that are affected by the new technology (mostly consumers and farmers).

**Cost Benefit Analysis**

The last methodological approach that is going to be presented is a Cost Benefit Analysis. It is very useful quantitative tool in measuring different opportunity costs and trade-offs of various approaches to genetic engineering. In 2003, Hall and Morgan assessed *A Partial Cost Benefit Analysis of the Introduction of the Genetically Modified Oilseed Rape Crops and Food to Scotland*. It can be discovered very easily that a direct valuation method (ascribing monetary value for different social, health, and
environmental risks) will be highly complicated. Authors of the study mentioned above offered an indirect valuation that “clarifies the opportunity cost of not advancing the technological development and then asks whether society values the avoidance of potential costs by this much” (Hall et al., 2003). When the costs and benefits are evaluated the best scenario program is chosen (the one with highest net present value). In their study, Hall and Morgan assessed benefits and costs for three separate categories: economic, environmental, and social. The main categories (groups that are affected by the implementation of a certain policy) that were identified for this particular study were GM farmers, non-GM farmers, local communities, GM companies, research institutions, secondary markets, consumers, and the government. The advantage of this methodology is that it can assess the same issue from different standpoints. For instance, the costs and benefits can be evaluated from the point of view of the consumers only. Another scenario: evaluation from the point of view of the biotechnology companies. It can be also evaluated from the point of view of society as a whole. This became to be known as “standing.” Thus, results of the cost and benefits analysis of a specific GM crop might change depending on who has the standing. CBA relies on the socio-economic research and the public involvement to gather needed information about value of the technology’s benefits and the value of avoiding its potential costs. Costs and benefits can be considered based on the factors discussed in the section 6.A of the present paper (such as markets, competition, trade, etc.). However, the disadvantage of this method is it lacks the qualitative analysis. Thus, answering such question as what are the costs and benefits with respect to religion, culture, and ethics becomes nearly impossible. Thus, for
effective decision-making purposes, results of the CBA analysis should be combined with, for instance, results of the sustainable livelihoods framework.

Based on discussion of socio-economic factors of GM crops presented in the previous section, I will assess a CBA analysis framework specifically with regard of those factors. One of the first socio-economic factors that have been discussed is distribution of benefits. CBA has to thoroughly approach this implication of GMOs by asking a question of how are the benefits and costs of the introduction of a certain GM product distributed amongst different societal groups. The second factor was public sector research and development. With regard to this factor, CBA has to evaluate how different R&D approaches affect various institutions. For instance, how will the results of CBA differ if they done by a public versus private agency and how these results are going to affect other institutions (e.g. FDA, EC, etc.)? In regards to the labor as a socio-economic implication of the GMOs, CBA has to be concerned with the question how will laborers and employees profit or lose with the introduction of various GM products.

“Markets” is another socio-economic factor that was discussed previously. In assessing CBA one has be concerned with which types of markets will benefit or lose (e.g. GM markets verses conventional or organic markets), what will be the effects on competition, what will be the consequences for the dependants of these markets? In the legal sphere, CBA has been concerned with intellectual property rights. The questions that have to be answered are what are the costs and benefits related to IPRs, how they affect producers, consumers, and research companies? As it was noted before, qualitative estimations are not the strongest part of CBA, however, some questions on ethic, culture, and religion can be assessed. That is, is there a monetary loss and control loss for some consumer and
farmers over their production and consumption choices with respect to the new GM product implementation? When assessing CBA, analysis standing plays crucial role. The final results of the CBA or the net present value estimation depend directly on the choice of standing. The author of the present paper believes that considerations and the assessment of the CBA has to be done from the societal perspective first and if the resources enable the researcher to conduct further analysis only then separate societal sectors have to be considered. Following steps of the CBA would include identifying benefits and costs for each of the socio-economic factors discussed above, estimating them in present value terms to assess long-term changes (note, choice of the discount rate will affect these estimation), and calculating net present value of the project. Based on the results recommendations can be made of how beneficial to the society the implementation and adoption of a particular GM crop could be. However, attaining the results is not an end in itself; they have to be incorporated into the decision-making process. There are four stages to bio-safety decision-making: the development of a domestic bio-safety “regulatory regime,” risk assessment for a certain GMO, short period after risk assessment, and grant or extension of the permit for import or adoption of a certain GM product. In this light, CBA has an advantage before other methodologies; it can be carried out on the very early stages of the decision-making process.

The list of the methodological approaches above is not final and each of the approaches has limitations. However, these methodologies can offer comprehensive analyses of the real impacts of the GMOs, conclusions of which can be successfully incorporated into the decision-making process on the bio-safety issues.
8. Conclusions and Recommendations

At last, we are able to answer questions that were raised at the beginning of this paper. In general, the development and diffusion of GM technology is well-described by Shumpeter's "process of creative destruction." Although, there is a lot of uncertainty and disagreement around genetic engineering today, the technology and its products steadily make their way onto the market. We can affirmatively say that if no extensive (and widely accepted) evidence of the harmful effects of GM technology on human health and environment can be presented in the future, it will become the leading technology in agriculture. The premises to this already exist: the wide support of GM by the government, industry producers, and the amount of research and development being put into the technology.

The main trends of the industry are: heavy investment in the research and development, vertical integration, world expansion, and high tendency of the firms to consolidation through formal and informal agreements. The analysis presented in this paper confirms that GE companies and the market in general have absolute and comparative advantage before the conventional industry through the ability to decrease the production costs almost in half with GM technology. Having this advantage, leading industry players, moved by the high profits, will eventually exploit gained market power. Already, this tendency can be noted.
Based on our analysis, the GM products being introduced into the market are not benefiting consumers or farmers. For example, farmers must pay for the seeds and for the chemicals annually, since in most cases they cannot reproduce the seeds for the second year. Also, as a result of more concentration in the agricultural industry, farmers will produce fewer wholesome produce and the market in general will be split between a few large corporations. Consumers, on the other hand, because they are not properly informed about the new technology, are not given a fair choice of accepting or rejecting it.

Organics are used as a higher-priced reference, so there is always “a cheaper” version of the same product offered. GE companies claim that they are working for the good of the consumers, farmers, and those in need (e.g. poor African people). However, the products that have been introduced on the market so far by large benefit corporations (African Center for Biosafety, 2006). Moreover, the more market power biotechnology companies gain the more incentive they will have to engage in price gouging. This will lead to lower consumer surplus and fewer consumer choices. Moreover, as discussed in this paper, the effects of the GE products on the human and animal health and the ecosystem are still not clear.

GE technology has also stimulated sales for pharmaceutical and chemical industries. The latter has benefited from the chemical resistant technology. What is more peculiar is that GE companies do not come up with crops that do not require complementary products or crops that proliferate for more than a year. This very fact exposes the true intensions that GE companies are after: market power and high profits.
The debate around Genetic Modification suggests that biotechnology is still risky business. For example, USDA officially recalled 500,000 bushels of soybeans because they were contaminated by the GM maize destined to produce vaccine for pigs. Most definitely, this kind of “product uncertainty” will raise any company’s costs. Thus, gene flow remains a problem and a barrier for the industry growth and development. Most GE companies are hoping for the development of a third generation of the biotech crops that can avoid this problem. It is also possible that the industry will be able to solve the discussed social issues and bring cost-efficiency to the agricultural, pharmaceutical, and food markets, thus, building strong advantage relative to the conventional agricultural industry.

In a sense, the change from conventional forms of farming to GE farming is a radical innovation related to the power of gene manipulation. Perfect fruit and vegetables grown every time, grains that are not affected by weeds and insects, crops that can withstand even the most harsh conditions on Earth – these are the great promises of GM technology.

This paper posed the question: “Can Genetic Modification really benefit humans and nature without bringing harm?” Unfortunately, today there is no definite answer to this question. GE technology has great potentials; however, great caution should be exercised by the interested parties (especially consumers and the scientific society) in approaching the issue of genetic modification. More sophisticated and extensive research should be done in this field. GE opponents would argue that GM technology only
benefits industry producers of GM products and the governments, but at the same time it imposes health and social threats to society.

At the present, it is difficult to side exclusively with either argument. They both have strengths and weaknesses. For instance, groups that are against GE do not have “agreed upon” criteria that are accepted by the scientific society facts of the negative effects of the GM products on human health and the environment (only individual scientific research is available). On the other hand, GE proponents compare positive effects of genetic modification only with chemical-based farming and do not consider organic farming and dismiss the health concerns all together. Moreover, their best argument for genetic engineering is its ability to deal with world’s hunger. However, it is obvious that the problems of poverty and starvation do not lie in the agricultural sphere (Food and Agriculture Organization of the United Nations, 2000). According to the analysis presented in this paper, there is not much evidence of societal benefits from GM technology. Even the positive effects of it can become negative in a long-term situation. Long-term costs, benefits, and risks of Genetic Modification remain largely unknown. In the opinion of the author, a holistic approach is needed. The social, economic, and political effects need more study to help address environmental and health concerns. The following recommendations can be made:

- To incorporate public sector research and development into overall development process of the new GE crops.
- To conduct studies targeted on the issues related to the labor markets to assess specific effects of the introduction of the GM products on this market.
• To obtain (for the government) relevant information on crops produced domestically, to collect information on their GM match produced abroad, to define the direction of exports of such crops and the consumer attitudes toward GM products on these markets.

• To clarify (for the government) trade policies on GM products and, since a favorable degree of certainty is still not achieved, to press global communities for a distinct segregation and labeling of such products.

• To consider the costs and benefits with respect to changes in competition. Moreover, the importance of public research and development can be called in help.

• To consider what are the long-term effects of the patent law implementation regarding GM products

• Not to discount ethical, cultural, and religious factors when considering the adoption of the GE technology. Recommendations can be also made to the public: social dialog, extensive discussions with various groups present and constant exchange of information should take place.

Moreover, in the light of two strong tendencies - fast concentration of GM markets and rapid development of the GE technology - emergence of a new and comprehensive methodological approach is needed in order to address socio-economic implications of the genetic engineering and effectively incorporate them into the bio-safety decision-making process. Ultimately, the question about safety of GM foods is a question about the well being of people and nature.
Appendices

Appendix 1.

**Table 1. Total Acres of GM Crops Planted and Percentage of all Crops that were GM in June 2003**

<table>
<thead>
<tr>
<th>Top GM soybean producing states</th>
<th>Top GM corn producing states</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Dakota: 2,294 74%</td>
<td>South Dakota: 3,375 75%</td>
</tr>
<tr>
<td>South Dakota: 3,731 91%</td>
<td>Nebraska: 4,160 52%</td>
</tr>
<tr>
<td>Nebraska: 4,042 86%</td>
<td>Kansas: 1,363 47%</td>
</tr>
<tr>
<td>Kansas: 2,349 87%</td>
<td>Minnesota: 3,763 53%</td>
</tr>
<tr>
<td>Minnesota: 6,004 79%</td>
<td>Iowa: 5,580 45%</td>
</tr>
<tr>
<td>Iowa: 8,736 84%</td>
<td>Missouri: 1,239 42%</td>
</tr>
<tr>
<td>Missouri: 4,109 83%</td>
<td>Wisconsin: 1,184 32%</td>
</tr>
<tr>
<td>Arkansas: 2,436 84%</td>
<td>Illinois: 3,108 28%</td>
</tr>
<tr>
<td>Wisconsin: 1,344 84%</td>
<td>Michigan: 805 35%</td>
</tr>
<tr>
<td>Illinois: 8,162 77%</td>
<td>Indiana: 912 16%</td>
</tr>
<tr>
<td>Mississippi: 1,210 89%</td>
<td>Ohio: 311 9%</td>
</tr>
<tr>
<td>Michigan: 1,533 73%</td>
<td></td>
</tr>
<tr>
<td>Indiana: 4,752 88%</td>
<td></td>
</tr>
<tr>
<td>Ohio: 3,256 74%</td>
<td></td>
</tr>
</tbody>
</table>

Table 7. * Number Rat Pups Died from the Litter of Individual Mothers on the GM-soy Flour Supplemented Diet

<table>
<thead>
<tr>
<th>Females</th>
<th>Number of newborn rats</th>
<th>Number of pups died</th>
<th>Number of dead pups/born (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female No. 1</td>
<td>11</td>
<td>7</td>
<td>64%</td>
</tr>
<tr>
<td>Female No. 2</td>
<td>8</td>
<td>4</td>
<td>50%</td>
</tr>
<tr>
<td>Female No. 3</td>
<td>13</td>
<td>6</td>
<td>46%</td>
</tr>
<tr>
<td>Female No. 4</td>
<td>13</td>
<td>8</td>
<td>62%</td>
</tr>
</tbody>
</table>

Table 8. * Examples of Absolute Values of Organ Mass in Pups in Three Weeks after Their Birth. Fixation in Formaldehyde 0.1M PBS, pH 7.2

<table>
<thead>
<tr>
<th>NN</th>
<th>Body</th>
<th>Liver</th>
<th>Lungs</th>
<th>Heart</th>
<th>Kidneys</th>
<th>Spleen</th>
<th>Testes</th>
<th>Brain</th>
</tr>
</thead>
<tbody>
<tr>
<td>N26 Normal</td>
<td>69</td>
<td>3.80</td>
<td>1.20</td>
<td>0.37</td>
<td>0.44/0.44</td>
<td>0.52</td>
<td>0.34/0.34</td>
<td>1.67</td>
</tr>
<tr>
<td>N27 Normal</td>
<td>72</td>
<td>4.63</td>
<td>1.55</td>
<td>0.38</td>
<td>0.52/0.42</td>
<td>0.81</td>
<td>0.3/0.3</td>
<td>1.6</td>
</tr>
<tr>
<td>N28 GM-soy</td>
<td>35</td>
<td>1.83</td>
<td>0.6</td>
<td>0.19</td>
<td>0.28/0.28</td>
<td>0.21</td>
<td>0.13/0.14</td>
<td>1.60</td>
</tr>
<tr>
<td>N29 GM-soy</td>
<td>30</td>
<td>1.68</td>
<td>0.5</td>
<td>0.20</td>
<td>0.19/0.20</td>
<td>0.19</td>
<td>0.14/0.18</td>
<td>1.54</td>
</tr>
<tr>
<td>N30 Trad-soy</td>
<td>62</td>
<td>4.28</td>
<td>0.95</td>
<td>0.36</td>
<td>0.38/0.38</td>
<td>0.24</td>
<td>0.22/0.26</td>
<td>1.76</td>
</tr>
<tr>
<td>N31 Trad-soy</td>
<td>63</td>
<td>4.35</td>
<td>0.94</td>
<td>0.39</td>
<td>0.42/0.42</td>
<td>0.32</td>
<td>0.22/0.23</td>
<td>1.66</td>
</tr>
</tbody>
</table>

References


References (Continued)


References (Continued)


References (Continued)


Wee, V., and Heyzer, N., Gender, Poverty and Sustainable Development, Engender, UNDP.

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