Modern Agriculture and Its Benefits – Trends, Implications and Outlook

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GLOBAL HARVEST INITIATIVE

Sustainably meeting the world's growing needs

Contents

I. Introduction

This section examines the benefits of modern-day agriculture—a task made necessary by the fact that an increasing share of the population has little connection to farms or rural areas—and thus little opportunity to understand the nature of farming, especially the modern advances that are both helping to better feed the world's people and better protect the environment.

Perhaps the chief paradox of agriculture's abundance is the fact that many of its enormous successes are providing the basis for new challenges. Chief among these, of course, is pressure from growing populations and increasingly wealthy developing-country consumers who want higher quality diets. To meet food demand expected by 2050, the sector must boost its capacity significantly in a relatively short period of time so that output grows by perhaps 70 percent or more over the next four decades, meets continuing future challenges in terms of protecting the environment and dealing with changing climates and does all this within a new economic and social setting—a growing competition for resources from urban, infrastructure and industrial users. And, it faces increasingly urgent constraints on the size and intensity of its environmental footprint.

This section precedes a description of what are often seen as missteps made as the sector has evolved and modernized. These involve concerns about environmental degradation, exposure to health hazards from food contaminants, animal abuses and many other real and perceived problems, including increasing economic concentration across the value chain to the detriment of smaller family-oriented operations and rural areas.

This drumbeat of criticism has seeped into the public consciousness in many cases and created a perception of a food system no longer held in high esteem by the general public despite the enormous benefits it has delivered over time.

In spite of such criticisms, the section argues that global agriculture is on track to accomplish its main goals within numerous important, new constraints—but that it remains vulnerable to inappropriate priorities and policies. Thus, it describes key challenges that extend both to the sector and to the general public including, especially, opinion leaders and policymakers. Its purpose is to help readers reach more fully informed views about agriculture, its needs, its objectives and the policies that should govern it.

Perspective—Meeting Society's Food Needs

In 1798, English philosopher Thomas Malthus famously argued that food production growth is inevitably limited by physical resource availability while population growth is geometric in its nature. He saw the food-population balance as always precarious because of physical resource limitations and the arithmetic growth potential.1

[1] Thomas Malthus, *An Essay on the Principle of Population*, 1798, Chapter 1.

Malthus thought this contrast must lead inevitabily to declining food availabiliy that—at subsistence levels—would threaten health and constrain fertility. Even when a population habitat was new – such as the American continent at that time, or when recovering from wars or epidemic plagues, he expected population to reach the limit of its resource base, and to do so relatively rapidly.

World leaders widely accepted the Malthusian "inevitability" for many years—but more recently have focused "anti-malthusian" policies in at least two directions. First, new social patterns have made population growth less relentlessly geometric, especially in Europe, the United States, and parts of Asia but elsewhere, as well. The world now expects continued growth, but at a slower pace. Global numbers are expected to grow from 6.5 billion in 2005 to a stable plateau of 9.1 billion by 2050, far below the path Malthus perceived, which would have meant more than 14 billion by 2050—without the intervention of disease or famine.

In addition, food production growth is no longer seen as tightly constrained even though many production resources are "fixed," or nearly so, as Malthus correctly perceived—including land and water. Since the 1950s, and especially over the last four decades, advances in output have been sufficient to support better and more secure diets for most of the world's people—although not for all, reflecting distribution problems rather than supply inadequacies.

For example, since the 1970s, as agriculture became increasingly modern, grain and oilseed production more than doubled—an increase of more than one billion tons—while planted area grew only modestly (Charts 1 and 2). Without this modern productivity, global output levels achieved last year would have required nearly 60% more land than actually was cropped.

A Look Ahead to Mid-Century

While the necessity of breaking Malthus' iron geometric-arithmetic link is widely understood and generally applauded, the means to that objective are frequently misunderstood. On the one hand, there is mounting evidence that the skillful application of science can allow the global population to better control its own development and growth. However, there also are powerful advocates of constraint for key aspects of modern systems—policy paths that, if adopted would have significant, negative implications for many of the world's people.

Chart 1. Global Grain Production, Consumption and Stocks, 1970-2008

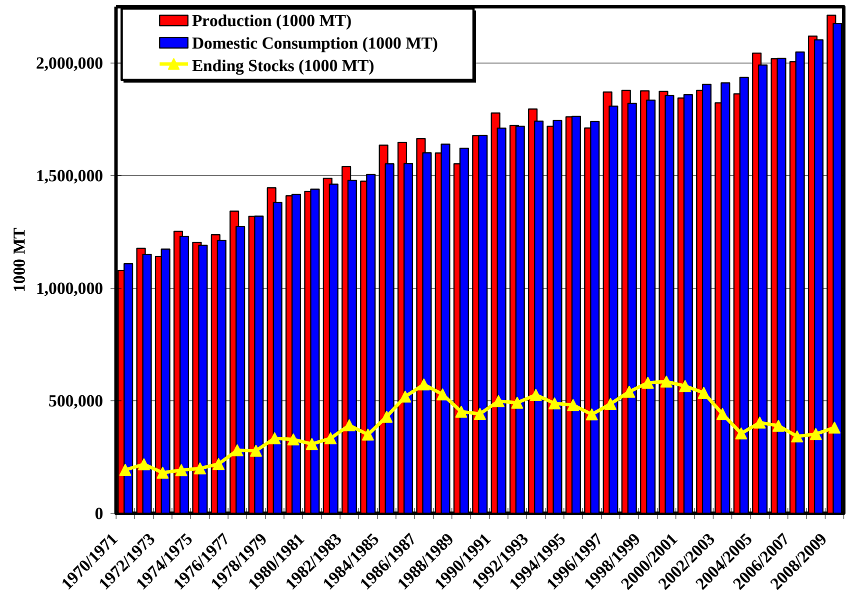
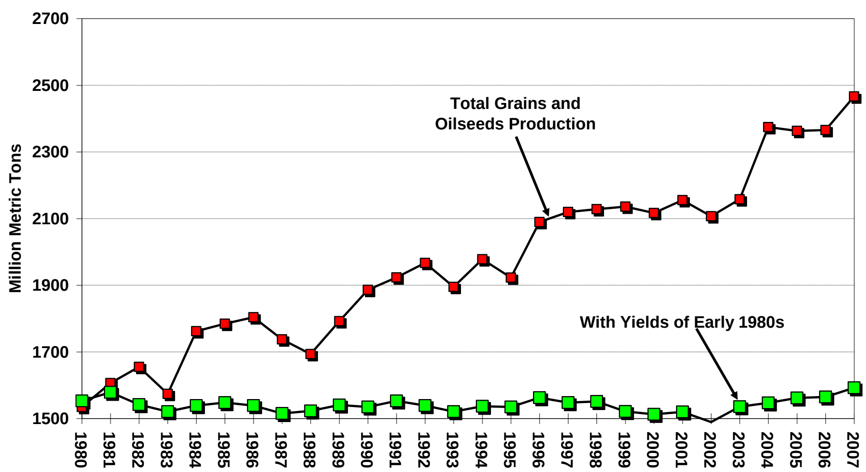


Chart 2. World Grain and Oilseed Production, With and Without Yield Advances since the 1980s



Source: Informa Economics

The New Challenge

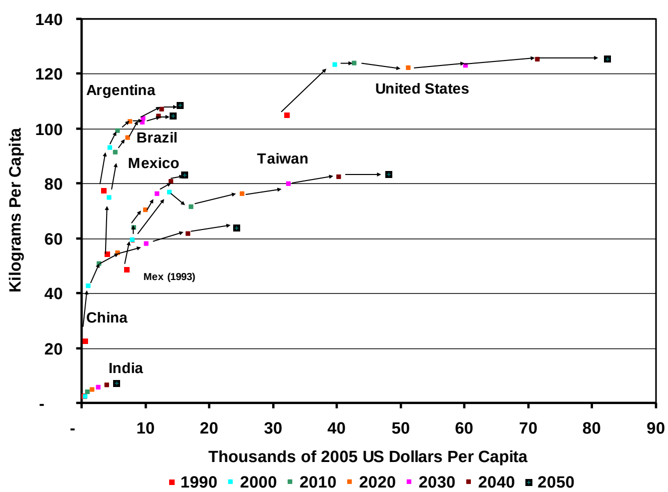
The main driver of global food demand in the future is the expanding purchasing power of middle-class populations in developing countries who are demanding higher quality diets. This trend has become especially important now as agricultural resource limits tighten at the same time competition for the same resources grows among urban, infrastructure and industrial users. The facts are clear:

- ***Population***. Today, the world has more than 6 billion people, with more than 5 billion of those in developing countries. Developing country populations are projected to continue to grow relatively rapidly—1.2 percent annually to 2030 before declining to a 0.9 percent annual average to 2050. By contrast, populations in industrial countries are projected to grow a more modest 0.3 percent annually to 2030 and 0.2 percent annually to 2050.

- ***Global Wealth***. While world population growth will be important to future markets for food, economic growth will be much more important. Not only has the rate of economic growth in developing countries come to outpace that in developed areas, but it has made them increasingly urban, as well.

  By 2050 global per capita income is expected to increase to nearly three times the 2005 level. While developed country growth continues at less than 2 percent annually, the pace in developing countries could exceed 5 percent per year, a trend reversal that began in the 1990s. This shift has enormous implications for global agriculture as it creates more and more higher-income consumers, (defined in terms of local economic conditions) with dramatically different food spending patterns.(Chart 3, 4, 5, and Table 1)2 It implies obvious benefits for millions of consumers, but also caries serious threats should agricultural productivity lag and basic foods become more expensive—an especially damaging trend for the poorest consumers.

Chart 3. Relationship Between Meat Consumption and Income per capita, 1990-50



Sources: Historical data based on FAO and USDA's PSD Database
Forecast from IHS-Global Insight, December 2009

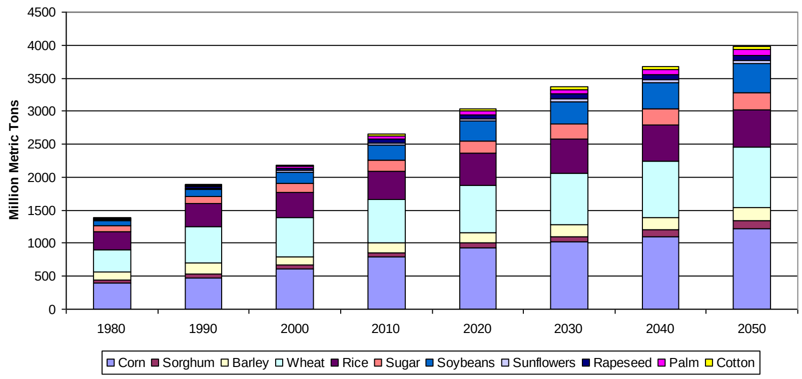
Thus, while there may be some uncertainty about exactly how fast global populations will expand, and how fast future economic growth will be in each part of the world, the directions of these

[2] See, for example, Collier, Paul, ***The Bottom Billion***, Oxford University Press, 2007; International Food Policy Research Institute, "***High Food Prices: The What, Who and How of Proposed Policy Actions***," Washington, D.C. May, 2008.

trends are clear—as are their implications for future food needs. These include increases in both crop and livestock demands on the order of 70 to 100 percent between 2000 and 2050. 3,4

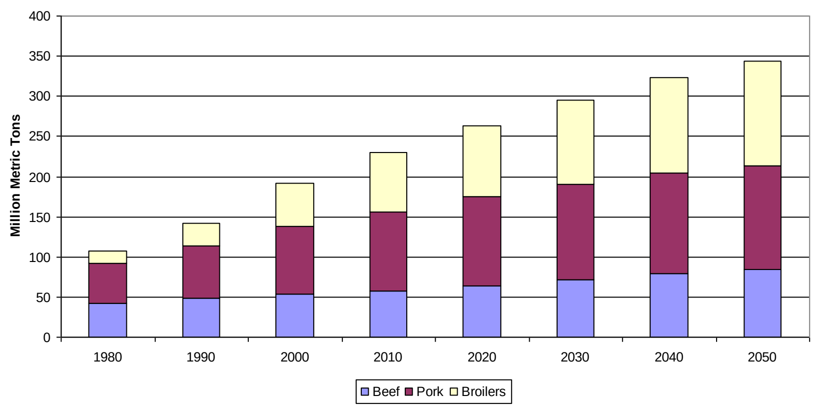
Current trends also provide some assurance that the necessary growth in food production can be achieved with continued application of modern technology, but not without it—a fact acknowledged directly by the Food and Agriculture Organization of the United Nations which observed last year that, "World agriculture has been able to meet the rapidly growing global demands for food, feed and fiber over the last half century….due to sizeable agricultural productivity growth…and will continue to depend on technologies promising….enhancement of productivity to sustainably managing natural resources in the future."5

Chart 4. Global Consumption Projected, Major Crops, 1980-2050



Sources: Historical data based on FAO and USDA's PSD Database
Forecast from IHS-Global Insight, December 2009

Chart 5. Global Consumption Projected, Beef, Pork and Broiler Meat, 1980-2050



Sources: Historical data based on FAO and USDA's PSD Database
Forecast from IHS-Global Insight, December 2009

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[3] FAO, ***How to Feed the World in 2050***, 2009
[4] FAO, ***World Agriculture Towards 2030/2050: Interim Report, 2006***
[5] FAO, ***How to Feed the World in 2050***, 2009

Table 1. Changes in World Crop Supply and Demand, 2000-50

<table>
<tr><th></th><th>Acreage Increase Required (2000 - 2050)</th><th>Trend Yield Increase Implied (2000-2050)</th><th>Production Increase Required (2000 - 2050)</th><th>Domestic Consumption Increase (2000-2050)</th><th>Stock Increase (2000-2050)</th></tr>
<tr><td>Corn</td><td>21%</td><td>71%</td><td>108%</td><td>102%</td><td>-10%</td></tr>
<tr><td>Sorghum</td><td>28%</td><td>60%</td><td>105%</td><td>100%</td><td>74%</td></tr>
<tr><td>Barley</td><td>13%</td><td>39%</td><td>56%</td><td>55%</td><td>19%</td></tr>
<tr><td>Wheat</td><td>-2%</td><td>60%</td><td>57%</td><td>56%</td><td>-5%</td></tr>
<tr><td>Rice</td><td>-2%</td><td>47%</td><td>44%</td><td>45%</td><td>-21%</td></tr>
<tr><td>Sugar Beets</td><td>-26%</td><td>87%</td><td rowspan="2">93%</td><td rowspan="2">93%</td><td rowspan="2">-18%</td></tr>
<tr><td>Sugar Cane</td><td>49%</td><td>43%</td></tr>
<tr><td>Soybeans</td><td>69%</td><td>51%</td><td>154%</td><td>152%</td><td>64%</td></tr>
<tr><td>Sunflowers</td><td>31%</td><td>66%</td><td>117%</td><td>115%</td><td>60%</td></tr>
<tr><td>Rapeseed</td><td>30%</td><td>81%</td><td>135%</td><td>124%</td><td>83%</td></tr>
<tr><td>Palm</td><td>NA</td><td>NA</td><td>266%</td><td>265%</td><td>75%</td></tr>
<tr><td>Cotton</td><td>4%</td><td>118%</td><td>127%</td><td>121%</td><td>47%</td></tr>
<tr><td>All Crops</td><td>15%</td><td>60%</td><td>80%</td><td>82%</td><td>-6%</td></tr>
</table>

Sources: Historical data based on FAO and USDA's PSD Database
Forecast from IHS-Global Insight, December 2009

Renewable Fuels—a New Dimension

While population and income growth are increasing global demand for agricultural products, new renewable fuels production priorities also have emerged and now consume significant amounts of sugar, grains and oilseeds in several countries. This growth has been both policy and market driven and reflects efforts to reduce the buildup of greenhouse gasses in the atmosphere and as well as concerns in many countries about dependence on volatile petroleum suppliers.

Two recent US energy policy laws enacted in 2005 and 2007 provide production subsidies, blending mandates and border protections against cheaper imports. Additionally, government R&D programs help the subsector boost production efficiency and support the development of new technologies for producing renewable fuels from non-grain commodities. The 2007 Act mandates that US motor fuel supplies include 36 billion gallons of renewable fuels by 2022, with about 15 billion gallons of that amount from corn and starch ethanol.

Somewhat similar policies in several other countries have increased global biofuel production rapidly, primarily in Brazil, China and India. All told, some 19 countries have significant biofuels programs with continued future growth likely given the current widespread political support for these programs. For example, global production of ethanol is projected to expand at nearly 6 percent annually for the coming decade, according to recent estimates and while biodiesel production is smaller, it also could increase rapidly. [6]

Considering Productivity

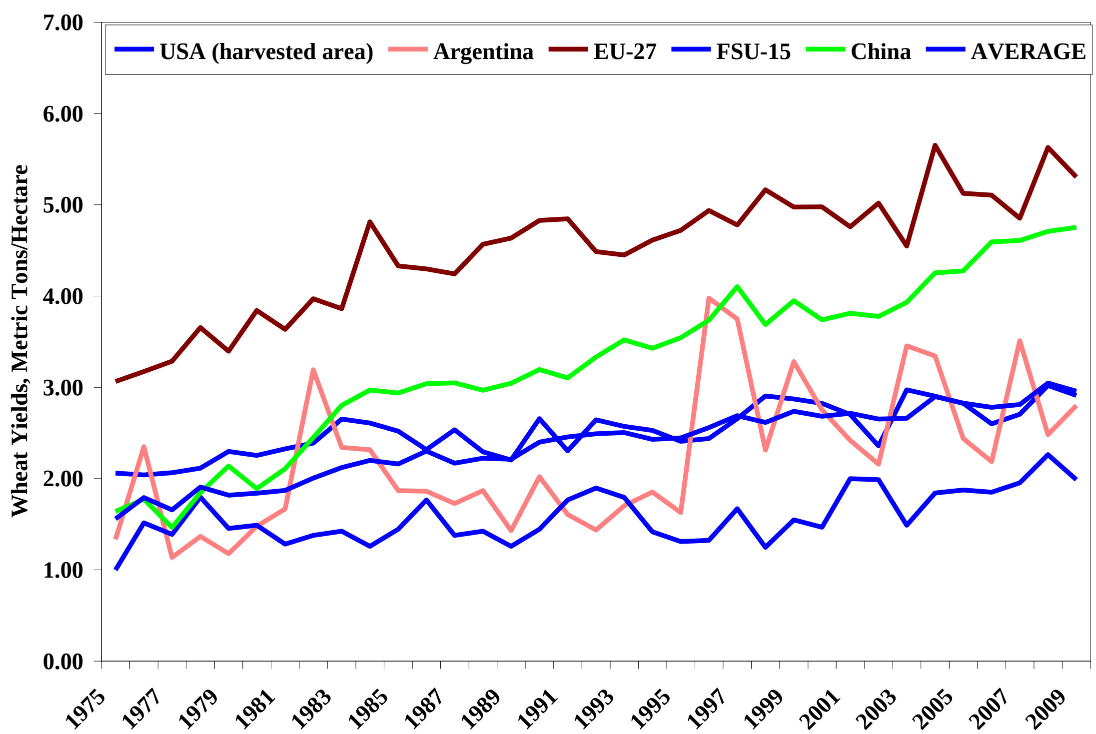
[6] OECD and FAO Secretariats.

While there is overwhelming evidence that global crop productivity has been growing for the past four decades, there is anxiety in many quarters about whether it is on pace to meet the demands for food expected by 2050—as well as whether the modest needs for additional production area can be met.

A primary indicator of productivity is crop yields and their growth, measures that reflect both natural factors, including soil fertility, growing season length and temperature, rainfall amounts and reliability or access to irrigation—and technology in the form of genetics, fertilizer, machinery, management practices, crop protection and other inputs; as well as credit to support their purchase. Since yields also depend on supportive agricultural infrastructure and linkage to broader economic systems, economic and trade policies provide useful indicators of the degree to which circumstances necessary for food production growth are present.

While the differences in yield trends among regions are great—especially between developed and developing countries—there is strong evidence that many developing areas can increase productivity significantly and some have been doing so for some time. China is a notable example. That country's average wheat yield has increased sharply in response to better market and policy incentives, access to improved inputs and the availability of broader technical assistance (Chart 6).

Chart 6. Wheat Yield Trends Compared, Selected Countries, 1975-09

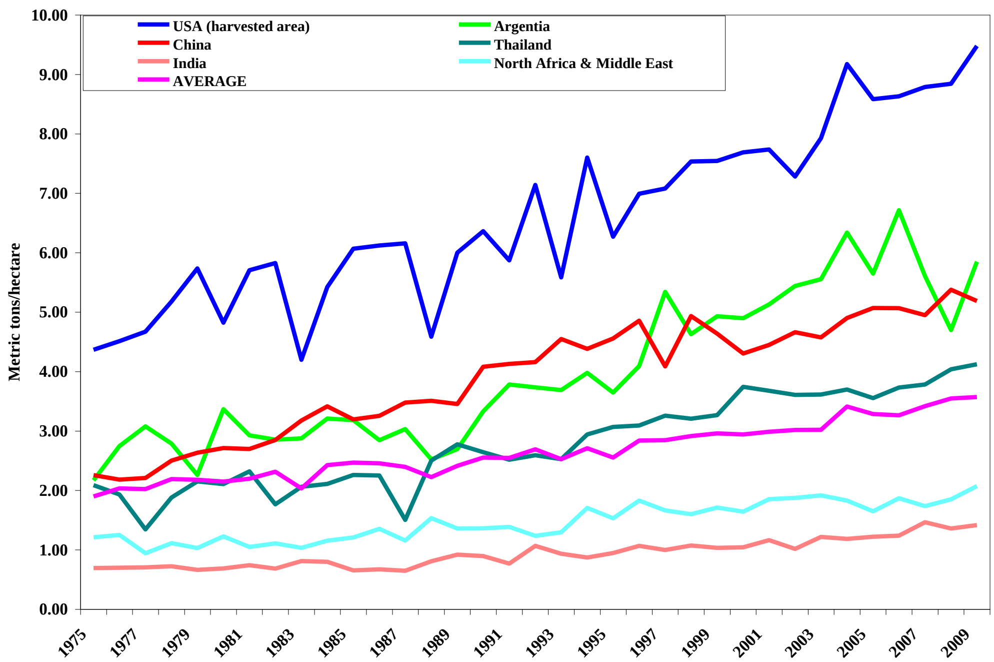


Source: Informa Economics

As a result, prospects seem strong for China's wheat yields to approach those of the EU-27 by 2020. India has used similar approaches, dating back to the beginning of the Green Revolution and its wheat yields also grew as a result. However, for most other producers, especially in developing countries wheat yield growth has been quite sedate.[7] However, the picture is very different for coarse grains.[8] (Chart 7)

For these crops, each of the major producers has yields that are consistently above the global average—and, for the United States and a few other producers, both the level and the growth rate are significantly higher than average.

Chart 7. Coarse Grain Trends Compared, Developed and Developing Countries, 1975-2009



Source: Informa Economics

In spite of rapid, sustained yield growth for most major producers in the past, there is concern that this growth may be slowing—and reviews of recent performance provide at least some support for such concerns. For example, only in four of the large producing countries did coarse grain yield growth accelerate in recent decades; the United States, Brazil and Argentina, and India. For each of the others, the yield growth rate declined. For the global average, Brazil and India, trends that were up for the earlier years of the period, but down significantly since 2005 (Table 2).

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[7] The yields in Chart were developed by Informa Economics, based on detailed evaluations of historical trends in individual countries and analyst judgment regarding expected future economic and agricultural policies, incentives, adoption rates and input quality, availability and prices. The trends implied are routinely evaluated and reviewed extensively by commercial clients, government agencies and others.

[8] Coarse grains include corn, sorghum, barley, oats and millet.

Table 2. Coarse Grain Yield Growth, by 5-year Intervals, Selected Major Producers, 1980-2020 (percent change)

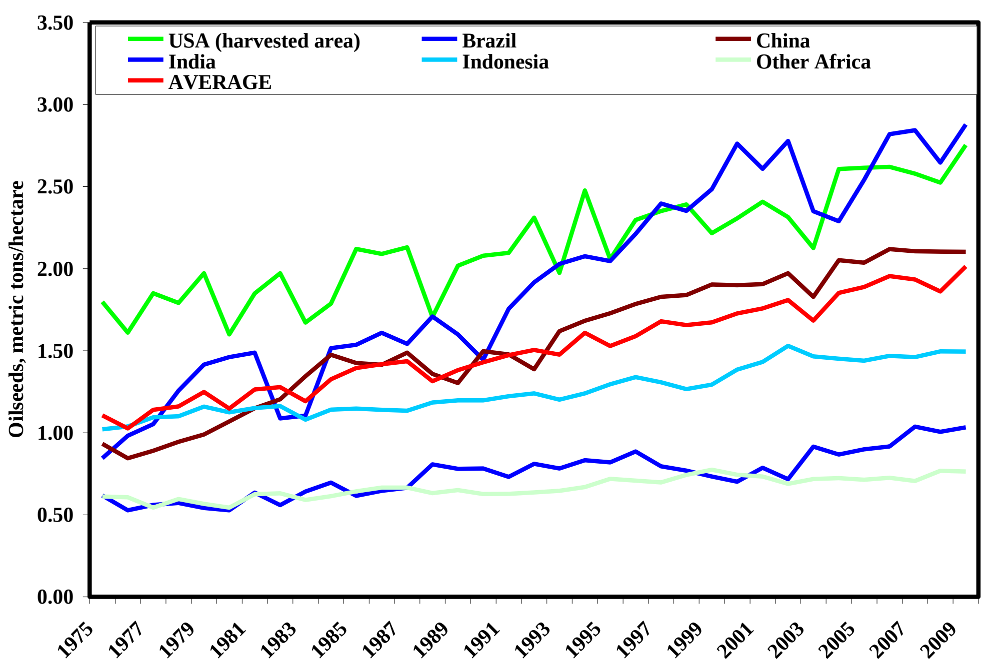
	'80a to '90a	'90a to '95a	'95a to '00a	'00a to '05a	05a to '10e	10e to '15e	15e to '20e	4 Decade Ave, %
USA	1.2	2.7	1.9	2.8	1.6	1.7	1.8	1.95
Brazil	1.1	5.2	2.6	2.5	3.9	2.1	2.2	2.80
Argentina	1.4	3.6	5.0	4.6	0.2	2.8	2.3	2.83
EU-27	1.5	-0.2	2.0	1.1	0.3	0.6	0.7	0.86
FSU-15	2.6	-1.9	2.3	5.1	1.7	1.3	1.0	1.73
China	3.8	3.4	-0.6	2.3	0.9	1.0	1.1	1.70
Thailand	1.9	2.8	3.3	0.5	2.9	1.6	1.5	2.06
India	2.1	2.2	2.3	2.4	3.3	2.1	2.4	2.41
Australia	2.6	-0.2	4.6	-4.9	3.3	1.8	1.2	1.20
NA&ME	2.2	4.3	0.5	0.5	1.6	-0.1	0.8	1.41
Ave	1.4	1.5	1.9	2.3	1.7	1.4	1.2	1.64

Source: Informa Economics

For the main oilseeds, the pattern is similar—sustained, high yield levels for the most competitive producers, including Brazil, Argentina and the United States along with rapid growth trends. The other main producers are successfully raising their yields, but frequently at a declining rate (Chart 8, Table 3).

The world's highest oilseed yields are in Brazil and the United States where yield growth has been especially rapid.

Chart 8. Yield Trends, Five Oilseeds, Selected Major Producers, 1980-2009



Source: Informa Economics

Table 3. Yield Growth, Five Oilseeds, Five-Year Intervals, Major Producers, 1980-2020 (percent change)

	'80a to '90a	'90a to '95a	'95a to '00a	'00a to '05a	05a to '10e	10e to '15e	15e to '20e	Average %
USA (harvested	1.3	2.0	0.3	2.5	1.0	1.8	1.3	1.47
Brazil	1.0	5.7	4.4	-0.5	2.7	1.2	1.2	2.23
Argentina	5.8	-0.6	4.9	1.8	1.2	1.2	1.3	2.23
EU-27	1.6	-0.2	2.0	2.8	-0.3	1.2	1.1	1.17
FSU-15	0.4	-4.8	-0.7	3.9	1.4	0.9	1.0	0.28
China	2.9	4.0	1.9	1.7	0.4	0.6	0.7	1.74
Thailand	4.4	2.4	-0.3	1.8	0.5	0.5	0.5	1.39
India	3.0	2.0	-2.6	3.8	3.0	1.0	1.1	1.63
Indonesia	0.5	1.4	1.2	1.2	0.4	0.3	0.4	0.77
NA&ME	-0.6	1.5	3.3	0.2	1.7	0.6	0.6	1.01
Other Africa	0.9	1.9	1.5	-0.8	1.2	0.9	0.9	0.93
Average	1.6	2.0	1.8	2.0	1.2	1.1	1.3	1.57

Source: Informa Economics, Inc.

Only three of the main global oilseed producers are projected to have higher productivity by 2020 than they did in 1980—Brazil, Argentina and NA&ME. For the United States, along with developing Africa, the trend is flat. For the global average, the yield growth trend is projected to be lower for the coming decade than it was during the 1990s. Thus, to continue to supply one of the world's fastest growing sectors of food demand, it will be necessary to allocate more—and, a greater share of the world's scarce cropland to meet future needs—unless productivity can be accelerated above current trends by more modern technologies.

The following sections discuss such technologies, in general, what they include and then the expectations they promote for global productivity growth in the future.

II. What is Modern Agriculture?

The "modernity" of agricultural systems is a characteristic well understood by farmers but not easily defined with specificity. Still, the distinctions between modern and traditional systems have powerful implications for the future development of the global food system—even though it is important to recognize that few, if any, systems fall entirely into either the modern or traditional categories.

Traditional systems. Perhaps the most important difference between the categories is the way farmers see themselves and their roles. Traditional farmers, for example, often say that they seek to work effectively with resources at hand. That is, they use the land, rainfall, seeds, tillage methods and power sources they have to produce what nature offers. Conventional processes are used to till the land, select and plant seeds, protect plants from competing plants and animals and gather the harvest. Surpluses are marketed through nearby outlets. Such producers frequently report only limited capacity to change these processes—and some seek to avoid change.

The productivity of such systems depends primarily on the natural fertility of the soils—enhanced by skillful care—and on the climate. The technology and management systems involved are often characterized by lack of access to, or reluctance to use new information about production and/or management, or public or commercial assistance. Their productivity tends to grow slowly, often in response to outside developments that reduce producer isolation, increase access to markets or support investment in water and land.

Modern agriculture. In modern agricultural systems farmers believe they have much more central roles and are eager to apply technology and information to control most components of the system, a very different view from that of traditional farmers. In contrast to the isolation inherent in traditional arrangements, modern agriculture tends to see its success as dependant on linkages—access to resources, technology, management, investment, markets and supportive government policies.

As a result, much of the success of modern systems depends on the development and maintenance of soil fertility through the specific provision of nutrients when they are depleted; of machine power and technology to create soil conditions necessary to promote plant growth with minimal disturbance and minimal soil loss; of the use of improved genetics for crops and livestock to enhance yields, quality and reliability; and, on modern genetic and other techniques to protect plants and livestock from losses to competing plants, diseases, drought insects and other threats.

This success also depends on access to efficient, effective irrigation to supplement rainfall in many climates; on advanced harvesting, handling and storage equipment and techniques to prevent losses and to market commodities efficiently. It depends, in turn, on both public and private investment to provide access to technology, equipment, information and physical facilities throughout the production-marketing system. And, it depends on well supported commercial and financial systems and broad public policies that support effective commercial markets at all levels that generate economic returns throughout the system.

Modern agriculture in developed countries including the United States involves far more than farms and farmers—it depends on enormous, highly sophisticated systems that move, store and processes producers' output throughout an extensive value chain that extends to food products and final consumers. For example, these activities taken together contribute well over $1.2 trillion to the US GDP annually and support nearly 24 million jobs (Table 4). And, while farm production and productivity are the bedrock of this system, they account directly for only small shares of the system's GDP and jobs—6 percent and 8 percent, respectively.

Table 4. US Agriculture's Contribution to GDP and Employment

	GDP %	Jobs	GDP mil $	Jobs thous
Farm	6	8	74.4	1896
Food Processing	14	5	173.6	1185
Textiles	2	3	24.8	711
Other Manufacturing	8	5	99.2	1185
Services	27	14	334.8	3318
Trade	27	35	334.8	8295
Transportation	3	2	37.2	474
Food Service	13	28	161.2	6636
Total	100	100	1240	23700

Source: ERS, USDA--2001 data, latest available

The sector's sophistication can be seen in the goods and services applied throughout the process. A key measure of its efficiency is reflected by the fact that US consumers spent only 9.6 percent of personal disposable income for food in 2008. By contrast, consumers in other parts of the world must spend 50 percent or more of their income for food, a fact that explains in large part, the wide divergences in standards of living.

III. Why Modern Agriculture is Important

There is really little mystery about why agriculture is important—it is the physical foundation of human energy, health, and physical well being—all key components of every important human activity. To the degree these components are missing, the human existence is defined primarily by the effort necessary to provide them. Making them more widely available at lower costs increases the capacity of any population to invest in more productive work, education, economic development and cultural activities.

Modern Agriculture's Crucial Role

The vital importance of food to physical, economic and cultural development, together with the importance of efficient, sustainable production makes modern techniques crucial—in fact, there is strong evidence that only such approaches have any significant chance of meeting the world's basic food needs in the next few decades.

In addition, they offer by far the world's best—perhaps only—prospect of dealing with growing future challenges to protect the environment and to deal with global climate change. Finally, modern techniques offers the only prospect of extending the food choices now available to the wealthy to the world's growing middle class.

The basic facts are clear:

- More people the world over eat more and better because of modern agriculture. Increased production continues to enable steadily improving diets, reflecting increased availability of all foods, dietary diversity and access to high-protein food products;
- The additional food modern systems provide has enabled hundreds of millions of people to realize more of their potential and better lives—thus enhancing the achievements of all, from students to retirees. It increases workforce productivity and generally supports human development and growth;
- The current hunger and malnutrition that extends to some one billion people reflects poor policies, low productivity and low incomes. Failure to continue to apply new technologies to advance productivity on the farm and across the food system simply worsens every aspect of these problems, especially those forced on individuals and families who live in poverty. To a very large extent, current food insecurity problems reflect bad policies, poor infrastructure and low economic productivity in the nations where these conditions occur, rather than a physical lack of food or food production capacity;

- The significant hunger and malnutrition that persist in many parts of the world would have been far worse had agricultural systems not grown and developed as they did;

- The physical pressures on the environment that have become increasingly prominent public concerns have been greatly ameliorated by modern agriculture, which has reduced:
  - The need to expand land area, and thereby reduced pressure to cultivate fragile lands and forested areas. Modern agriculture includes successful new technologies, including biotechnology to enable both higher yields and reduced environmental impacts. These reduce the land, fertilizer and pesticide use per unit of output;
  - Pressure on grassland, forestland and cropland thus increasing wildlife habitat as a result;

- While the unintended negative environmental consequences of modern agriculture are frequently noted, little mention is ever made of the negative environmental impacts that frequently arise from smallholder farming, especially from "slash and burn" primitive systems in wide use in developing countries where vertical rows are often planted up steep hillsides, resulting in some of the world's heaviest soil erosion, badly polluted watercourses and many other problems of both efficiency and sustainability. The lack of sustainability of these practices can be seen in the fact that they typically lead to abandonment of successive plots year after year;

- Processing technology and handling advancements contribute enormously to improved food safety through pathogen reductions and large reductions in post-harvest losses that

A View from Industry—Consumer Choice and the Importance of Modern Agriculture

1. The global food industry needs technology. Without advancements in agricultural technology, humanity would likely not have progressed through the 20th century without major famines or devastating food wars. Will we be able to say the same thing at the end of this century, given that a food crisis is already here? I believe the answer is *yes,* because I concur with the U.N. that 70 percent of this food must come from the use of new and existing technologies and methods. And these technologies and methods must have no negative impact on the environment, animal welfare or food safety.
2. Consumers deserve the widest possible variety of safe and affordable food choices. In general, consumers trust food producers to keep the food supply safe, and they're more concerned about food contamination than about technology used on the farm. Instead, one of the most pressing human concerns about food is affordability. For this reason, consumers from all classes and geographies — from those who can afford organic foods to those who struggle to maintain a diet that sustains them — must be allowed to choose from an abundance of safe, nutritious and, most importantly, inexpensive food options.
3. The food production system can mitigate the food economics challenge and achieve an "ultimate win." Facing a global food crisis, the world is at risk through the midpoint of this century. We already see the signs: our population consumed more grain than we produced during seven of the last eight years. The good news: an "ultimate win" is still possible. What will it look like? Five key achievements will mark its success:

- **Improving the affordability of food** by using new and existing technologies and optimal productivity practices.
- **Increasing the food supply** by instituting a vastly improved degree of cooperation across the entire global food chain.
- **Ensuring food safety** with a combination of technology and high quality standards and systems, coupled with a greater measure of worldwide collaboration.
- **Increasing sustainability** through a highly productive and efficient system that simultaneously protects the environment by means of sensitive and efficient use of natural resources.
- **Producing more biofuels** to reduce dependence on fossil fuels while creating no negative effect on global food supplies.

Jeff Simmons, President of Elanco Animal Health, the animal health division of Eli Lilly and Company

further increase food supplies. Pasteurization of milk, canning, freezing, and other processing technologies significantly reduce health risks associated with food. Threats from bacteria and other contaminants are still important, but the risks of illness and death are far less than in the past, a fact that is widely underappreciated;

- Modern agriculture brings enormous economic and social benefits to consumers including:
    - Improved quality of life and living standards as food costs decline. This effectively raises consumer incomes since it leaves greater purchasing power for other consumer goods, for education, health care, leisure, etc., a trend that has been a major driver of economic growth in developed countries, and in some developing countries, as well. Today, consumers in the United States spend less than 10% of their disposable income for food while many in the developing world spend from half or more of their income on food, a huge drag on quality of life. It is now widely recognized that the development of modern food system has been a major factor in improving the standard of living enjoyed in much of the world today;

- When consumers spend the major share of their income and virtually all of their daily efforts simply to find food, little money or time is left for human investments. This "survival treadmill" characterizes the lives of most smallholder farmers, especially in developing countries;

- Modern agriculture increases global political stability by making more food available, improving its quality and making it accessible to more people.
    - Without the advances that characterize modern agriculture, the world arguably would be a much more dangerous and volatile place because more people would be food insecure—as the food price spikes of mid-2008 clearly illustrated.
    - Development of a robust, rules-based trading system has been extremely important in improving food distribution and increasing accessibility in food-deficit areas.

The major threat to modern agricultural development comes not from lack of interest and willingness to invest by farmers, but from increasingly vocal opposition from a constellation of activists who have succeeded in shifting agricultural policies in several areas. This threat is discussed in detail in the following sections.

IV. A New Challenge—Updating the Social Contract

Most developed nations traditionally invested heavily over time in their agricultural systems to insure access to the food products they need as they grow and expand. This involved a highly complex, although often implied "social contract." Society was expected to support for various aspects of a competitive, commercial agricultural sector that assured abundant supplies of healthful food and fiber products, in response to consumer demands expressed through efficient markets. The system also was expected to generate private investment sufficient to maintain future growth.

The government commitment also frequently included support in the form of public investment in critical infrastructure, market information and regulation, basic research and development, training and education in a number of key areas—as is done for most other important economic sectors.

The primary benefit from this investment has been agriculture's strong productivity growth—passed on through the enhancement of national economic well being in the form of more abundant food available at declining shares of disposable income. In addition, the agricultural sector was expected to share its productivity with the world, especially developing countries through both competitively priced food exports and through aid programs.

Despite this long standing arrangement throughout most developed countries, agriculture today frequently finds itself in the crosshairs of critics who are keen to impose their own, often utopian views on how agriculture should be organized.9 These are frequently based on very different economic and social objectives than those typically assumed in the original contract as it evolved over the years. Some would go so far as to replace the modern system with small organic homesteads and urban gardens in an effort to return agriculture to some "traditional" state—or, at least, to constrain additional growth or use of non-traditional technologies.

Many such visions are not just aspirations, but are predicated upon a wide array of charges against the modern sector made by activists in support of a broad range of causes. These are often joined by a growing group of writers, columnists, journalists and others (including some public officials) who share their views.[10],[11]

This barrage of criticism frequently reflects real concerns about the environment, food safety and other perceived threats, but that is not always the case, it must be said. Many others reflect little more than vague promises of greater pleasure from a new "food culture" and of a quieter, factory free, pollutant free system with enhanced animal care. Some are based merely on the assertion of "tensions" between modern agriculture and nature.

Utopian views and efforts to organize and live in accordance with them are not new, of course—history is replete with examples. What is new is the willingness and capacity of some activists to attack the modern system for its success, its growth and expansion and its prosperity, and then to

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[9] One aspirational term in vogue just now to describe desired sector changes is "sustainability." The concept is broadly defined in the 2008 farm Act in terms of things that sustainable agriculture systems should accomplish and include satisfying the human need for food and fiber, enhancing environmental quality and the natural resource base upon which agriculture economy depends, making the most efficient use of nonrenewable resources and on-farm resources and the integration, where appropriate, of natural biological cycles and controls. These are seen as sustaining the economic viability of farm operations and enhancing the quality of life for farmers and society as a whole. Source: ***Dr. Roger Beachy, NIFA Director and USDA Chief Scientist, USDA Outlook Forum 2010, February, 2010.***

[10] These complaints are frequently based on assertions of links to national health—growing obesity, especially in children; growing incidence of Type II diabetes; incidence of autism and many others. For example, one widely-read critic of today's food system, Michael Pollan, claims a "…fundamental tension between the logic of nature and the logic of human industry."

[11] ***Ibid***.

argue that utopian approaches can better achieve even better, although amorphous goals based mainly on separate criteria they use to define those objectives.

Agriculture's Second Debate. Increasingly, activists concerned with agricultural issues are willing to abandon long-standing public policy criteria and assert entirely new ones without regard for the conflicts they imply.[12] Examples of some of these and a few of the conflicts involved include opposition to:

- Commercial agriculture and larger-scale farms regardless of whether the operations have grown on the basis of their efficiency or not. In many cases, activists no longer feel the need to debate, but simply declare their opposition to "factory farms" or "industrial agriculture" without definition or justification—and, especially without discussion of the practicality or the economic or social cost of the changes proposed;

- The use of modern, science-based agricultural inputs and processes. These tools including agro-chemicals, modern genetics, modern machinery and others have been found to contribute to sector efficiency and growth, and their use has long been heavily regulated and monitored on the basis of standards that are frequently re-evaluated. Activists often propose abandoning or restricting the use of these inputs in spite of the absence of credible health threats—and ignore the consequences of such policies for consumers and other stakeholders, in the United States and overseas;

- Biotechnology and its use in agriculture for any purpose, especially when based on the private ownership of the genetic advances. These widely-regulated technologies, now used by millions of farming operations for decades without damage to humans or the environment vastly improve productivity. Still, activists often oppose their use simply on the basis of a "precautionary" principle that defeats rational debate and has the potential to harm many in the future;

- Non-local foods. Many local foods have an advantage in freshness, flavor and cost when they are in season. Beyond that, presuming advantages for local foods unrelated to those based on economics, availability or tastes and preferences again implies higher prices for consumers, far narrower food choices and much smaller production than the current system provides;

USDA Chief Scientist on the "Sustainability" Debate

"So why then are discussions about sustainability so charged? First, I believe it's because we have framed or allowed others to frame sustainability as a practice itself or a set of practices. It's not. Sustainability is a goal, and therefore the focus should be on outcomes rather than specific practices. Certainly both science and field experience are leading to a better understanding about what practices there should be and under what circumstances, and should move us closer to sustainability. But as with any goal, it is important to keep the focus on the goal and be open-minded about ways to achieve the goal." *Dr. Roger Beachy, NIFA Director and USDA Chief Scientist, USDA Outlook Forum 2010, February, 2010*

[12] The willingness of some activists to abandon long-standing public policy objectives, criteria and principles is counter to both public and private efforts to define and apply "science based" standards as the basis for many human interactions in trade, product acceptance, medical care and in other areas. These shifts in the social contract implicitly reject those and instead rely upon personal perceptions or other notional criteria.

These challenges to "modernity" are enormously important because they have the potential to limit agriculture's capacity to meet global food needs. Clearly, food production systems designed to maximize "cultural experience" without regard for technical production effectiveness or efficiency have little chance of achieving the scale needed to meet future food requirements; or reducing the environmental impacts of production; or, of dealing with climate change. And, policies designed to rely only on energy from the sun, as some activists urge, certainly hold little promise for large numbers of the world's people who lack resources.

The US Sector Overview—an Example. The United States has in place today a large, highly efficient food system that can accommodate many degrees and types of preferences and levels of purchasing power. It also has a history of insisting that food policies be understandable and based on science, unlike the often un-definable, un-testable "precautionary principle" revered in some parts of Europe and widely used when scientific analyses do not yield the results wanted. Furthermore, the utopian model being promoted by much of the urban media and food-intellectuals has little to do with the essential structure and organization of American agriculture.[13] Despite assertions that the sector is "corporatized," families own almost 96% of the nation's 2.2 million farms, including the vast majority of the largest operations. Small-scale agriculture, rather than being driven out, is on the upswing with growing numbers of such operations, although—after years of rapid growth—organic foods and beverages still account for less than 3 percent of US food sales.[14] And, scientifically advanced farming and larger-scale operations produce the vast majority of the foodstuffs consumed by the average American family, as well as the bulk of US exports.

V. Benefits of Modern Agriculture—The Record

While the phrase, "industrial farming" is frequently intended to deride modern farm organization, it is impossible to ignore the fact that agriculture, like other sectors, has become much more productive as machines and computers have eliminated the most laborious (and, dangerous) parts of the job.[15],[16] And farming communities have educated their children to choose, in many cases, other careers—and the number of people who want to work on farms in the old, labor-intensive way is very small. The result is that hand-labor-intensive crops (e.g., coffee, strawberries…), or high labor cropping systems (e.g., organic) appear to be on a collision course with demographic trends, since the pool of unskilled, low cost farm labor upon which those crops and systems have depended appears likely to continue to decline—and increasingly to make non-mechanization an increasingly non-viable option.

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[13] Joel Kotkin, distinguished presidential fellow in urban futures at Chapman University, America's Agricultural Angst, Jan 19, 2010, Forbes Magazine.

[14] US Agricultural Census, 2007.

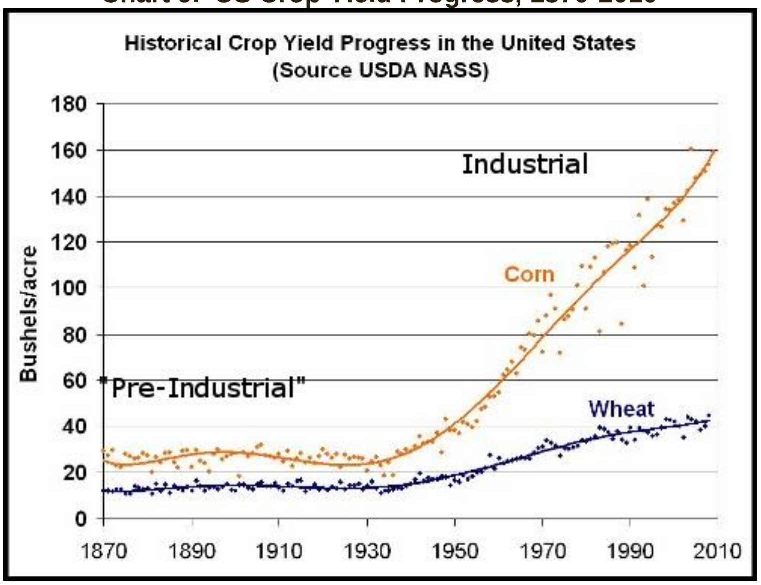
[15] Based on article by Steve Savage Published on February 4th, 2010, posted on agriculture, food crisis, food safety.

[16] A detailed history of farm equipment on the John Deere website traces the drop in the workforce directly involved in farming from ~40% in 1900 to less than 1% today

At the same time, modern agriculture has become much more productive (Chart 9). "Pre-industrial" yields were low and stagnant before introduction of better machines, synthetic fertilizers, improved plant and animal breeding, pesticides and, most recently, biotechnology and the huge changes these new techniques brought. At the same time, it is true that environmental issues that led to the Dust Bowl calamity of the 1930s also led to the establishment of the Soil Conservation Service and other important steps that continue to improve farming practices through public and private programs until they have all but eliminated wind and water erosion hazards.

For example, the pioneers of "no-till" agriculture actually began in the early 1960s in efforts to save fuel and stop erosion. And, the environmental movement of the late 1960s lead to the creation of the Environmental Protection Agency in 1969—and to major changes in pesticides and pesticide regulation since that time.

Chart 9. US Crop Yield Progress, 1870-2010



A few relatively simple practices have had great success in protecting both soil and water quality and are being widely adopted now. These include:

- Continuous "no-till," which saves fuel, stores soil moisture better, eliminates erosion and off-site movement of pollutants, increases biodiversity;
- Cover-cropping, which when combined with no-till leads to net carbon sequestration, and can be used either to produce biologically fixed nitrogen or to scavenge excess nitrate as needed;

- Controlled wheel traffic, which saves fuel, stops compaction, reduces nitrous oxide emissions; and
- Precision, variable-rate fertilization which increases the efficiency of fertilizers and reduces their needs and reduces emissions of nitrous oxide.

Today, agriculture uses strong links to public and private input providers and others to maintain and increase efficiency and productivity, and to do so on a sustainable basis. The results have been the steadily higher yields that were documented and discussed earlier—and contrasted with trends elsewhere in the world, and trends toward even stronger growth in the future.

Productivity Growth Sources. Modern productivity growth comes from many directions—and, depend on technologies that are attractive to producers because they boost their incomes and have been doing so globally for many years (Table 5). These include, but are not limited to biotechnology and better genetics. By 2007, biotech crops were grown in 18 countries and were estimated to increase farm income by more than $10 billion. During the decade 1996-07, these increases were valued at more than $44 billion (Table 5).

Agro-Technology Facts

The magnitude of the yield increases reflecting new technologies is highly impressive in a number of cases.

For example, corn yields increased 1.8 bushels per acre per year from 1975-1995. More recently, new technologies have enabled increases of 3.2 bushels per year from 1995-2005—77 percent greater growth.

An example of how these technologies cut costs can be seen from the pest controls they offer. Modern practices have helped producers control pests—for example, “baseline” European corn borer losses ran 25 bushels per acre in recent university studies, but Bt corn provides more than 99 percent control of corn borers. And, it improves on producers’ “traditional” option, two passes with insecticides that provides only 60-80% control and can destroy beneficial insects in the process.

Table 5 Global Farm Income Benefits from Biotech Crops, 1966-07

Global Farm Income Benefits form Growing Biotech Crops, 1996-07, million US $

Technology:	Increase in farm income: 2007	1996-07	2007 income benefit: *Share, country value, % **	*Share global value, %*
Herbicide tolerant soybeans	3,935	21,814	7.2	6.4
Herbicide tolerant maize	442	1,508	0.7	0.4
Herbicide tolerant cotton	25	848	0.1	0.1
Herbicide tolerant canola	346	1,439	7.65	1.4
Insect resistent maize	2,075	5,674	3.2	1.9
Insect resistent cotton	3,204	12,576	16.5	10.2
Others	54	209	na	na
Total	10,081	44,068	6.9	4.4

**** share of value of production in adopting countries***

Source: Brookes, Graham and Barfoot, Peter, ***GM Crops: Global Socio-economic and Environmental Impacts, 1996-2007***

Evidence of agriculture’s persistent adoption and use of new technologies comes from around the globe, and includes both large and small-scale operations. Plantings of biotech varieties are continuing to grow—some 330 million acres used biotech technologies in 2009, up about 7 percent over 2008. The United States continues to be the leading user of this technology with

158 million acres planted last year, but Brazil likely will have the largest gain with 53 million acres planted by 150,000 farmers, mostly in soybeans, a 35 percent increase from 2008.[17]

Argentina, with the second largest biotech area in 2007, fell to third, but still relies more heavily on biotech crops than India, Canada and China. China planted 9.1 million acres of biotech crops - mostly cotton - last year, but its recent approval of genetically modified rice and corn suggests plantings there will expand soon. Genetically modified corn and rice will be field tested for two or three years before being planted commercially.

USDA reported in June, 2009 that 91 percent of the US soybean crop was biotech varieties. For corn, 85 percent was genetically modified as was 88 percent of the cotton.

The Ayele Case: How Improved Maize Hybrids Allowed Expansion and Strengthened Family Support

Situation

Debebe Ayele, a 46-year-old Ethiopian farmer, lives in a densely populated area of southern Ethiopia.

Prior to working with Ethiopian representatives of Pioneer Hi-Bred, a DuPont business, Debebe lived in a grass roof thatched hut that needed constant repairs and maintenance. His family farm was three hectares; averaging 1.5 metric tons of maize per hectare. He owned an ox and two indigenous-breed cows. His annual income averaged $1,100, unless drought caused a crop failure. “Our population is increasing at an alarming rate and usable land is limited. My biggest concern was how to feed my large family,” said Debebe.

Solution

In 1995, Debebe began working with Pioneer Ethiopia agronomists and planting improved Pioneer seed along with fertilizer and other crop inputs. In the decade that followed, Debebe has been able to make significant improvements in his farm’s productivity and his family’s life.

Impact

As a result of planting hybrid seed and adopting new management practices, maize yields increased to eight to 10 metric tons per hectare. Increased income allowed him to purchase better inputs for other crops.

Debebe expanded his farming operations from three hectares to 10 hectares (seven hectares is contracted). He purchased seven more oxen and two improved-breed dairy cows to provide more milk.

Debebe’s yearly net income increased to more than $6,000. He is a model farmer for the district and now a farmer-dealer for Pioneer.

In Debebe’s words:

“I like Pioneer people because they bring good products, and their advice and support to change the community lifestyle is beyond our expectations.

Now, I feed my family the whole year, my thatched house is changed to corrugated iron sheet and I am sending all my kids to school with proper school supplies. I am paying school fees and accommodation for four of my kids studying at private college. I bought a television and radio for entertainment, agricultural news and now watch grain prices. I bought improved dairy breeds of cows and we earn reasonable income from supply of milk to the community, I also contracted a better storage facility, and constructed 10 rooms for rent in town, collecting US $60 per month.”

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[17] ISAAA is a U.S.-based biotechnology monitoring group funded by a wide variety of public and private interests including the US Agency for International Development, Monsanto, CropLife International, USDA and others.

Although agricultural productivity growth has been widely distributed globally, its focus and much of the resulting benefits of biotechnology have been concentrated in a relatively few agriculturally developed countries, including the United States, China, India, Argentina, Brazil, Paraguay and Canada (Table 6).

Table 6. Farm Income from Biotechnology, by Country and Crop, 1996-07

GM Farm Income Benefits, 199602007, Selected Countries, US $							
	GM Herbicide Tolerant Crops:				GM Insect Resistant Crops:		Total
	Soybeans	Maize	Cotton	Canola	IR Maize	IR Cotton	
United States	10,422.0	1,402.9	804.0	149.2	4,778.8	2,232.7	19,789.6
Argentina	7,815.0	46.0	28.6	na	226.8	67.9	8,184.3
Brazil	2,868.0	na	na	na	na	65.5	2,933.5
Paraguay	459.0	na	na	na	na	na	459.0
Canada	103.5	42.0	na	1,289.0	208.5	na	1,643.0
South Africa	3.8	5.2	0.2	na	354.9	19.3	383.4
China	na	na	na	na	na	6,740.8	6,740.8
India	na	na	na	na	na	3,181.0	3,181.0
Australia	na	na	5.2	na	na	190.6	195.8
Mexico	8.8	na	10.3	na	na	65.9	85.0
Philippines	na	11.4	na	na	33.2	na	44.6
Romania	92.7	na	na	na	na	na	92.7
Uruguay	42.4	na	na	na	2.7	na	45.1
Spain	na	na	na	na	60.0	na	60.0
Other EU	na	na	na	na	12.6	na	12.6
Columbia	na	na	na	na	na	10.4	10.4

Source: Brookes, Graham and Barfoot, Peter, ***GM Crops: Global Socio-economic and Environmental Impacts, 1996-2007***

Biotech Crop Technology Benefits—Overview

Biotechnology has, to date, delivered specific agronomic traits designed to overcome production constraints for perhaps 12 million of the world's farmers[18]. This has resulted in improved productivity and profitability from the technology applied to over 111 million hectares in 2007, and has made important, positive socio-economic and environmental contributions even though only a limited range of agronomic traits have been commercialized so far, for a small number of crops.

The technology has delivered economic and environmental gains through a combination of their inherent technical advances and by facilitating the use of technology in more cost effective and

Examples of Small Farmer Benefits from Biotech

Insect-protected Bt cotton has been adopted by several million small farmers in developing countries such as China, South Africa, and Mexico.

- In China, a 1999-2001 survey of farmers demonstrated three-year average increased yields from Bt cotton of 523 kilograms per hectare (24%) over non-Bt cotton. Three-year net economic returns per hectare averaged US$332 for Bt cotton versus a loss of US$138 for non-Bt cotton -— a difference of US$470.
- In South Africa, a three-year analysis of 2,200 small farmers from the Makhathini area demonstrating consistently higher yields and increased revenues for Bt versus non-Bt cotton farmers. Bt cotton farmers experienced increased gross margins of 531 to 742 South African rand per hectare (equivalent to US$86 to $93) versus non-Bt cotton farmers over the study period.
- In Mexico, a study documented the economic benefits of Bt cotton during 1998. The study demonstrated increased yield of 0.29 tons per hectare and reduced expenditures on seed and pesticides of US$83 per hectare, creating a net economic advantage of US$626 per hectare for Bt cotton farmers versus non-Bt cotton farmers

[18] Source: Brookes, Graham and Barfood, Peter, *GM Crops: Global Socio-economic and Environmental Impacts, 1996-2007*, PG Economics Ltd, UK, 2009 "

environmentally friendly farming practices. More specifically:

- The gains from the insect resistant traits have mostly been delivered directly from the technology (yield improvements, reduced production risk and decreased the use of insecticides), so farmers (mostly in developing countries) have been able to both improve their productivity and economic returns while also practicing more environmentally friendly farming methods;

- The gains from herbicide tolerant traits have come from a combination of direct benefits (mostly cost reductions to the farmer) and the facilitation of changes in farming systems. Thus, herbicide tolerant technology (especially in soybeans) has played an important role in enabling farmers to capitalize on the availability of low cost, broad-spectrum herbicide (glyphosate) and, in turn, facilitated the move away from conventional to low/no tillage production systems in both North and South America.

This change in production systems has made additional positive economic contributions to farmers (and the wider economy) and delivered important environmental benefits, notably reduced levels of GHG emissions (from reduced tractor fuel use and additional soil carbon sequestration):

- Both insect resistant and herbicide resistant traits have made important contributions to increasing world production levels of soybeans, corn, cotton and canola.

Other Productivity Drivers—More Efficient Machines.

These not only help drive productivity growth but also provide a broad range of other benefits. Examples include:

- ***The John Deere 8530 row-crop tractor emits 50% less particulate matter*** and 30% less nitrogen oxide than its predecessor did just 6 years ago. Even with lower emissions, it set an all time record as the most fuel efficient row crop tractor ever tested in the Nebraska Tractor Tests. In addition:
    - GPS aided machine control reduces tillage, fertilizer, seed, fuel and pesticide inputs by 5-10% per acre;
    - Major improvements in engines and power trains are continuing. Part of the increase is due to engine efficiency and part comes from advances in transmission technology that enables the operator to control ground speed for the most productive, most efficient use in different field conditions. Those same fuel efficiency/clean air improvements have occurred with the farmer's crop care and harvesting equipment as well, so the impact is multiplied;
    - Today John Deere's smallest harvester is more productive than its largest machine in 2000. In growing agricultural economies like Russia, a single John Deere combine often is used to replace 2-3 outdated, less fuel efficient machines.

- ***Planting, crop care and harvesting equipment can be equipped with global positioning and other data links*** to ensure high efficiency and more environmentally friendly farming. Pass-to-pass overlaps of 5 to 10 percent were common for field operations in the past, which meant that most every acre consumed more tillage, more fertilizer, more fuel, more pesticides etc., than required.
    - This technology has reduced farmer costs, reduced environmental footprints and resulted in much more efficient output per acre. More recent products automatically turn

individual planter and sprayer components on and off based on their specific position in the field, leading to yet another 3% reduction in seed, fertilizer and pesticides on a per acre.

- On-board yield sensors and application data now enable farmers to understand production variability across farms and fields to focus on individual zones or grids in their fields and then manage inputs precisely. Using GPS-referenced data, they can tailor inputs for maximum efficiency and minimum environmental footprint. For example, fertilizer application equipment can use the GPS data gathered from a harvester to vary just the right amount of plant nutrients as it passes from grid to grid in the field. That means placing precisely the right amount of nutrients for optimal yields. Again, that reduces environmental impact, decreases costs and provides the "best" yield per acre.

- ***More sophisticated planting equipment*** allows growers to take better advantage of improvements in plant genetics. Narrower rows shade the ground quicker and reduce dependence on herbicides. Seed meters are calibrated to handle seeds with different treatments that reduce the need for pesticide passes. Nutrient injection equipment allows the farmer to fertilize and plant at the same time, reducing the need for additional passes through the field. And field data are recorded for analysis against yield and pest pressure to reduce inputs and applications on an ongoing basis.

- ***Water use efficiency continues to increase.*** Conservation tillage systems provide a valuable mulch to reduce evaporation from dryland and irrigated systems. Laser guided scraper systems provide precision land leveling that improve efficiency of flood / furrow irrigation and rice production systems. Advanced irrigation technologies, including drip irrigation, provide for increased water efficiency and precision application.

- ***Tillage passes are being reduced by planting equipment*** that can plant through much more crop residue than in the past. Many farmers formerly used three tillage passes per year as recently as 1985, and now use only one or no passes saving at least 1.5 gallons of diesel fuel per acre or another 208,000 btus per acre. Reduced tillage also means less soil erosion, improved soil tilth, conservation of water, and less carbon emissions.

Benefits from Improved Management

While yield increases and cost decreases help make the new technologies attractive, they also require more active, better management to realize their full potential. For example, plant breeding efficiencies are increasing at a remarkable rate, in addition to the development of transgenic crops, simply by finding more efficient ways to track, sort and apply data to improve the plant breeding work begun in the 1930's. For example:

- Agronomists have coaxed 32% more yield per pound of nitrogen from corn since 1985. Since each pound of nitrogen represents 24,500 BTU's of energy input, the modern corn farmer uses over 1 million BTU's less per acre of corn than they would have needed to achieve today’s yields in 1985.

- Through molecular breeding yield increases, nitrogen efficiency and water efficiencies are making corn production even more efficient and sustainable from an environmental standpoint

Beyond Yield Increases and Cost Savings

Addition benefits from use of new technologies, including biotech varieties include cleaner grain and earlier seeding resulting in higher yields. For example, biotech canola has produced cleaner grain—and, producers are receiving 50% less dockage. And, farmers also gain from earlier seeding opportunities that result in higher yields. Examples of other benefits include:

- 63% of all US soybean farmers who reduced their tillage practices since 1996 list herbicide tolerant technology as the key factor;

Reduced tillage and the Conservation Reserve Program have been widely cited by producers surveyed as key factors behind a reduction of soil erosion by 1 billion tons per year;

- Reduced soil erosion results in less sediment polluting water -– saving US consumers an estimated $3.5 billion in 2002 in water treatment and storage, as well as waterway maintenance, navigation, flooding and recreation costs. The result is cleaner, more affordable drinking water for consumers;
- Farmers are saving more than 300 million gallons of fuel per year through reduced tillage approaches which also decrease greenhouse gas emissions;
- Reduced tillage dramatically improves agricultural land as habitat for wildlife. Earthworm populations are three to six times higher in a no-till field than in a field that's plowed, while quail can find their daily food in about one-fifth the time in a no-till field compared to a field farmed with conventional;
- Reduced tillage methods reduce soil erosion, increase moisture availability for growing crops, and improve wildlife habitat.

Environmental Impacts of New Technologies

Since 1996, the use of pesticides on the biotech crop area was reduced by 359 million kg of active ingredient (8.8% reduction), and the overall environmental impact associated

Esajian Farms Case

Gary Esajian's family has been farming in California's Central Valley since the 1920s, and now raises fruits and vegetables on 6,000 acres in Fresno and King's Counties, typically producing processing tomatoes, almonds, walnuts, pistachios, wine grapes, wheat, cotton, alfalfa, garlic, and onions. Through innovative agricultural practices, the farm has succeeded in growing more with fewer inputs.

Gary began growing processing tomatoes in 1997, which now occupy most of his acreage. A typical acre produces 40 tons of tomatoes, thirty percent more than in 1997—with reduced inputs. For example, since shifting from flood to drip irrigation, he uses 25-40% less water per crop. Given recent droughts in California and a spot price for water of $400 per acre-foot, saving water is a big deal—made possible by shifting to drip irrigation, a big investment that paid for itself in two years. Years ago, it took one employee to manage the irrigation for 160 acres but today one person manages seven similar plots. In another area of the farm, one employee manages the irrigation for 1500 acres of trees and vines.

By applying most nutrients and chemicals through the irrigation system, Gary reduces input costs and minimizes runoff. Modern fertigation and chemigation are good both for business and for the environment.

Mechanization plays an important role in helping boost efficiency in his operation. By leveraging GPS technology as he installs his irrigation and plants his tomato crops, Gary reduces machine passes in the field. In this way he drives down fuel and labor costs while increasing output.

Like many growers, Gary faces the challenge of how to increase the farm's output, and reducing input use per unit of output. To adapt to these market realities, Gary continues to employ new technologies and approaches, helping to close the global agricultural productivity gap.

with herbicide and insecticide use on these crops was reduced by 17.2%;[19]

- The largest environmental gain has come from the adoption of biotech herbicide tolerant soybeans. The volume of herbicides used in biotech soybean crops decreased by 73 million kg (1996-2007), a 4.6% reduction, and, the overall environmental impact associated with herbicide use on these crops decreased by 20.9% (relative to the volume that would have probably been used if this cropping area had been planted to conventional soybeans). Even though some countries increased production and herbicide use, environmental impacts were positive since farmers switched to herbicides with a more environmentally benign profile;

- Major environmental gains have also come from the adoption of biotech Insect Resistant cotton. These gains were the largest of any crop on a per hectare basis. Since 1996, farmers have used 147.6 million kg less insecticide in IR cotton crops (a 23% reduction), and this has reduced the associated environmental impact of insecticide use on this crop area by 27.8%;

- In the maize sector, herbicide & insecticide use decreased by 92 million kg and the associated environmental impact of pesticide use on this crop area decreased, due to a combination of reduced insecticide use (5.9%) and a switch to more environmentally benign herbicides (6%). In the canola sector, farmers reduced herbicide use by 9.7 million kg (a 13.9% reduction) and the associated environmental impact of herbicide use on this crop area fell by 25.8% (due to a switch to more environmentally benign herbicides).

Indirect Farm Level Impacts from Technology Advances

As well as the more tangible and quantifiable impacts on farm profitability, researchers are identifying a number of other important, although intangible impacts associated with the use of new technologies. For herbicide tolerant crops the main benefits are:[20]

- increased management flexibility and convenience that comes from a combination of the ease of use of broad-spectrum, post emergent herbicides like glyphosate and the wider window for spraying;

- reduced damage to crops by inputs. In a conventional crop, post-emergent weed control relies on herbicide applications before the weeds and crop are well established to achieve maximum efficacy, and crop growth may suffer from the effects of the herbicide. In a herbicide tolerant crop, this problem is avoided both because the crop is tolerant of the herbicide and because spraying can occur at a later stage when the crop is better able to withstand the treatment;

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[19] Source: Brookes, Graham and Barfood, Peter, *GM Crops: Global Socio-economic and environmental Impacts, 1996-2007*, PG Economics Ltd, UK, 2009

[20] Since the early 2000s, a number of farmer-survey based studies in the US have attempted to quantify these non pecuniary benefits. These studies have usually employed contingent valuation techniques. Drawing on this analysis, the estimated value for non pecuniary benefits derived from biotech crops in the US (1996-2007) is $5.11 billion, equal to 26% of the total cumulative (1996-2007) direct farm income. Similar benefits are likely to have accrued in other countries, but have not yet been quantified.
Source: Brookes, Graham and Barfood, Peter, *GM Crops: Global Socio-economic and Environmental Impacts, 1996-2007*, PG Economics Ltd, UK, 2009

- facilitation of conservation and no tillage systems, which mean additional cost saving benefits such as reduced labor and fuel costs as plowing is reduced, in addition to greater moisture retention and reductions in levels of soil erosion;
- improvement in levels of weed control, which contribute to reduced harvesting costs – cleaner crops and reduced times for harvesting. It has also improved harvest quality and higher quality bonuses in some regions and years (eg, herbicide tolerant soybeans and herbicide tolerant canola in the early years of adoption respectively in Romania and Canada);
- elimination of potential damage caused by soil-incorporated residual herbicides in follow-on crops;
- reduced need to apply herbicides in a follow-on crop because of the improved weed control.

For insect resistant crops the main benefits include:

- improved production risk management by eliminating concerns about significant pest damage;
- reduced management time, a convenience from reduced needs for crop walking and applying insecticides;
- savings in energy use – mainly associated with less use of aerial spraying;
- savings in machinery use (for spraying and possibly reduced harvesting times);
- better crop quality. There is a growing body of research evidence relating to the superior quality of insect resistant corn relative to conventional and organic corn and the reduced incidence of mycotoxins;
- improved health and safety for farmers and farm workers, from reduced handling and use of pesticides, especially in less developed countries where many apply pesticides with little or no use of protective clothing and equipment; and
- shorter growing season (eg, for some cotton growers in India) which allows some farmers to plant a second crop n the same season;

VI. Observations—Looking to the Future

The foregoing sections make the case that global food challenges have intensified steadily in recent years, especially since the beginning of the 20^{th} Century—when the world's population was only 1.6 billion people and global needs could be met by increasing yields and agronomic improvements—and, fossil fuels became increasingly essential in the development of machines to replace animal power, and to allow production of fossil fuel-based ammonium fertilizers.

Now, at the beginning of a new century, the global population is much larger—6.1 billion in 2000 and expected to exceed 9 billion by 2050. The combination of population and economic growth, especially in developing countries means that the world must nearly double food production—yet again—but, in only the next 40 years. This daunting challenge is further exacerbated by resource limits that mean that available arable land will be approximately static while availability of water and nitrogen could decline—even as new challenges associated with climate change begin.

It also is clear from this discussion that that the only feasible approach that can permit the world to meet the competing demands it faces while more effectively dealing with its physical, economic and social constraints is through increasingly rapid innovation and productivity growth. It also has shown that these goals are feasible, given the necessary public and private support, including support for both continued modernization of agriculture and food systems in the developed world, and for more effective assistance for developing nations to modernize their agricultural sectors. It also emphasized the need to build in new and more effective safeguards all along the way to minimize the unintended problems that sometimes arise.

Across agriculture today and in many of the world's most powerful institutions, there is a growing consensus that the sector is well positioned to meet expected 2050 needs at the same time it undertakes to **alleviate the poverty, hunger and malnutrition now afflicting more than one billion people**. Numerous prestigious international groups have assigned their most urgent priorities to these concerns, including, for example, the G-20 group of international leaders, the Food and Agriculture Organization of the United Nations in its recent food summit, the World Bank, the Bill and Melinda Gates Foundation and the Royal Society of London, among many others. Each has advocated urgent attention to agriculture, food security and the alleviation of hunger, malnutrition and poverty.

Statement by Patricia Woertz, ADM Corporate Board Chair and CoChair World Economic Forum

The world is looking to agriculture to do more to meet growing needs for food, feed, fiber and industrial products, and to do so sustainably—all against a backdrop of constrained natural resources and growing challenges.

Like many in agriculture, we at ADM believe that agriculture can sustainably grow to meet rising demand. To ensure that agriculture achieves its promise, we think its going to take innovation—on the farm and throughout the agricultural chain—investment—particularly in infrastructure—and partnerships—with all who have a stake in the sustainable development of agriculture to meet our global needs.

We think there are four approaches to meeting growing global demand:

- First—preventing the post-harvest loss of what is already grown;
- Then, making the most efficient use of those crops;
- Next—improving productivity on existing land; and
- Last, where possible, sustainably bring some additional land into production

However, meeting these challenges will require continuous progress, building on past successes and taking advantage of technology—challenges increasingly well understood across the industry. And, it will require increasingly supportive and effective policies, which take long periods of time to design and implement. Today, there is a growing consensus across the sector that at least six specific actions are needed to achieve the necessary progress, including:

- Increased public and private support for agricultural research and extension;
- Increased public support for agricultural infrastructure investment, especially in developing countries but in developed countries, as well;
- Better organized and supported foreign aid with much greater emphasis on agriculture, agricultural productivity and development;
- Systematic efforts to improve agricultural policies globally, including new emphasis on open markets and effective, feasible and equitable safety nets for producers and for private, as well as public risk management;
- Reduced barriers to agricultural trade; and
- Renewed focus on negotiations to reduce barriers to technology and to increase reliance on science-based international sanitary-phytosanitary rules.

Agriculture's Challenge

"One way to get this incredible challenge in our heads is to realize that we need to produce as much over the next 40 years as we have in the last 10,000 years, and do so on about the same amount of land. We can likely add another 10-12 percent to our production area, but each year added cultivation comes at an increasing environmental cost.

We need to accomplish most of this through yield gains. And, we will need to do this in the face of physical challenges like less water to irrigate, changes in the climate, and —equally important—challenges to the sector's image because we'll live in a world which is increasingly urbanized, and influenced by social media that may have unfounded and unrealistic opinions about farming.

If we don't manage to communicate well, it will have a profound impact on our capacity to farm with modern, efficient methods, on the availability and affordability of everyone's food, and the economy as a whole." ***Jerry Steiner, Executive Vice President of Sustainability and Corporate Affairs, Monsanto Company***

Statements by industry leaders broadly support these commitments. For example, in 2008, Monsanto announced a new program to develop sustainable yields that include producing more, conserving more, and improving lives—and the company is now making the investments to develop seed to double yields with traditional and advanced breeding, protected by biotechnology traits that deliver when coupled with the farmer's innovation. The company is committed to accomplish this doubling with each bushel produced using one-third fewer resources. Its statements indicate that it is prepared to invest about $1 billion a year, or $3 million every day to reach these objectives, and that it now believes its research pipeline is delivering results that reflect these overall commitments.

The Monsanto commitment clearly is one of several, and fully reflects increasing agricultural and agribusiness confidence that it will find the necessary tools to meet global needs, do it environmentally and economically on a sustainable basis for the entire system—the challenge for the next 40 years.

VII. Summary

This paper observes that the threats to human well being that Thomas Malthus saw more than two centuries ago are still real, important and potentially dangerous. While the world can afford more optimism now than it could then, achieving the goals of a better-fed global population with fewer impoverished people, better protected resources and more effective strategies to deal with the changing climate is still an enormous challenge. The paper concludes that these goals are certainly possible <u>with</u> modern agriculture, but <u>not without it</u>. And, it suggests that these challenges are not well understood by many of the world's increasingly urban people.

The paper discusses what modern agriculture is, and the keys to its potential success—ever more effective control of the many processes it employs, achieved by harnessing expertise and support from the full range of private and public sources and avoiding the isolation inherent in traditional systems.

However, a major stumbling block on the path toward meeting future food needs is seen emerging from efforts by perhaps well-intentioned people who would change society's long-standing contract with agriculture, in spite of both enormous successes in better feeding the world's people and in confronting the daunting challenges still before us. Such critics often urge that key public policy criteria be abandoned and entirely new ones asserted without regard for the conflicts this implies or where it would lead.

Utopian visions are certainly not new, of course, but many of today's food activists attack the modern system for its successes—its growth, efficiency and prosperity while offering only amorphous alternative goals based mainly on separate, personal objectives rather than the established public policy criteria they spurn. It is clear, for example, that food systems intended to maximize "cultural experience" without regard for technical production effectiveness or efficiency have little chance of achieving the scale needed to meet future food needs, let alone deal with environmental problems or climate change. And, policies designed to rely only on energy from the sun, as some activists urge, certainly hold little or no promise for large numbers of the world's people who lack resources.

Many activists misstate reality in another way, as well, the paper suggests. Despite assertions that the modern food production is "corporatized," it is not. For example, in the United States, families own almost 96 percent of the 2.2 million farms, including the vast majority of the largest operations. Small-scale agriculture, rather than being driven out, is on the upswing with growing numbers of such operations, although—after years of rapid growth—organic foods and beverages still account for less than 3 percent of US food sales. Scientifically advanced farming and larger-scale operations produce nearly all of the foodstuffs consumed by the average American family, as well as the bulk of US exports.

The paper then discusses a range of benefits modern agriculture already offers, including greater production and income for farmers (including very small producers) in both developed and developing countries, sharply reduced environmental impacts from recent cuts in pesticide, herbicide and fertilizer use along with less tillage and less land and water use per unit of output—developments that decrease pressure on fragile global ecosystems. And, it points out that many important human benefits result as smaller shares of disposable income are needed to purchase food—including enhanced economic well-being and improved social stability as food insecurity is avoided.

The paper concludes with comments on industry commitments to the science, technology, and investment in the sector's capacity to keep global development on the track defined by modern economic and social needs. It concludes that in spite of immense challenges, future technology needs are increasingly well understood so that with improved public understanding of the importance of these investments, global agriculture can reasonably expect to achieve the difficult objectives being established for the next 40 years.

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