The Global Harvest Initiative

2010 GAP Report™

Measuring Global Agricultural Productivity

This paper outlines the calculations behind the new Global Agricultural Productivity Report™, developed to measure ongoing progress in achieving the goal of sustainably doubling agricultural output by 2050. For the first time, the GAP Report™, including the GAP Index™, quantifies the difference between the current rate of agricultural productivity growth and the pace required to meet future needs – while limiting the environmental footprint of agriculture. This 2010 GAP Report™ is the initial step in providing a benchmark and eventually prescriptive actions that will help to strategically increase productivity in selected regions of the world.

Farm Foundation, NFP developed the calculations in this report using data provided by the Economic Research Service of the U.S. Department of Agriculture. They predict that doubling agricultural output by 2050 will require increasing the rate of productivity growth to at least 1.75 percent annually from the current 1.4 percent growth rate, an increase of 25 percent per year.

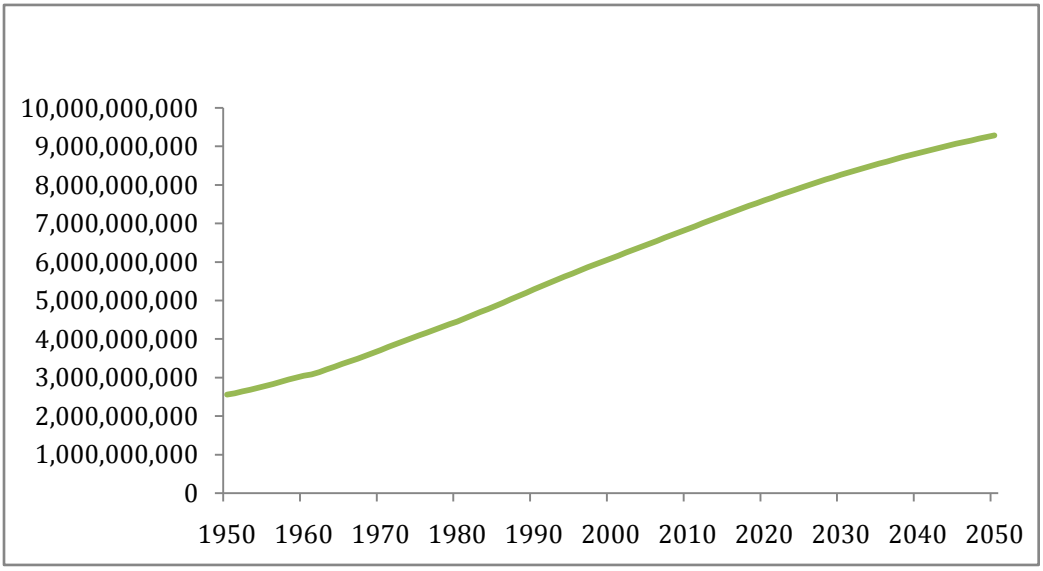
An electronic version of this report is available at www.globalharvestinitiative.org. Updates on global productivity as new data is collected can be tracked at www.agproductivity.org.

The Challenge

Meeting future demand for agricultural production

By 2050, when the planet's human population is projected to peak, agriculture will be challenged to provide the necessary food, feed, fiber, fuel, and other uses to meet the world's needs. In just over 30 years the world population will pass 9 billion people (Figure 1), an increase of nearly 50 percent from today's level. Most of this growth will occur in the developing world as developed nations approach zero population growth.

Figure 1. World Population



Source: U.S. Census Bureau. International Database. (Retrieved September 16, 2010). Available from: www.census.gov/ipc/www/idb/region.php

While the recession has put the brakes on income growth in the last two years, the global economy is beginning to recover. Throughout history we have experienced economic ups and downs. But over each decade since World War II, the world has experienced rising per capita wealth. Growth has been most rapid in the developing world, not only increasing demand for food staples, but also bringing changes in dietary preferences. Unlike consumers in the mature food markets of higher-income countries, income growth will lead developing-country consumers to increase the quantity, quality, and types of food they purchase. At very low income levels, consumers meet most of their calorie needs with staples, typically cereal grains or starchy roots and tubers. However, as incomes rise and the transition begins from subsistence to middle class, consumers begin to diversify their diets by eating more meat, dairy products, edible oils, fruits and vegetables. Today, cereals and root and tuber crops make up more than 60 percent of the diet of the world's population. By 2050 the Food and Agriculture Organization (FAO) of the United Nations expects that these staples will make up only 54 percent of food consumption, while animal proteins (meat and dairy) and vegetable oils will rise to nearly 40 percent of the global diet, up from about one-third today (Figure 2). These estimates do not include fresh fruits and vegetables, for which demand is also expected to rise substantially.

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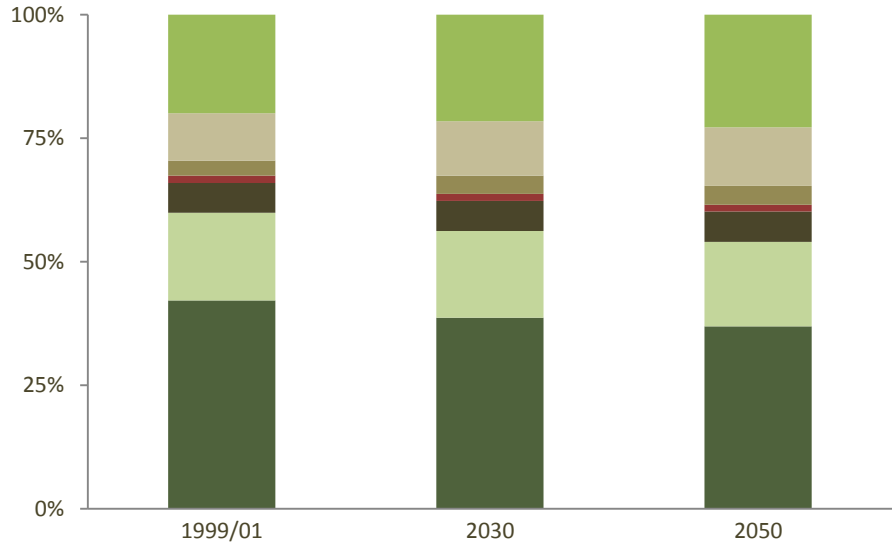
Figure 2. The Changing Global Diet



	1999/01	2030	2050
Milk and dairy, excl. butter (fresh milk eq.)	78.3	92	100
Meat (carcass weight)	37.4	47	52
Vegetable oils, oilseeds and products (oil eq.)	12	16	17
Pulses, dry	5.9	6	6
Sugar (raw sugar eq.)	23.6	26	27
Roots and tubers	69.4	75	75
Cereals, food	165.4	165	162

Source: *World Agriculture: towards 2030/2050. Interim Report. Prospects for food, nutrition, agriculture and major commodity groups*, Table 2.7, Food and Agriculture Organization of the United Nations, Rome, June 2006.

A growing population, increasing incomes, and changing consumption patterns will mean a substantial growth in the demand for food. At a 2009 international conference on food security, FAO Director General Jacques Diouf declared that global agricultural output needed to double by 2050. The FAO 2006 *Interim Report* indicates a 70-percent increase in food demand alone by 2050. But even doubling agricultural output would not be sufficient to bring an end to hunger and under nutrition in the world. The FAO estimates of the demand for agricultural production by 2050 assume that nearly 4 percent of the population in developing countries, or nearly 300 million people, will remain undernourished. If development and poverty reduction are successful in curtailing those numbers, then the demand for food and agricultural production will be even greater.

Food and feed are not the only sources of increasing demand for agricultural output. Agriculture is an important source of fiber, energy, and industrial raw materials, and the demand for these non-food uses of agriculture commodities is also likely to grow in the future. But rising demand is only half of the picture faced by world agriculture in the 21st century. The challenge is whether agricultural supply can rise sufficiently to meet these demands without forcing food prices up or seriously degrading the environment.

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Concerns about a returning Malthusian crisis in food supply are not new. In the two centuries since Malthus published *An Essay on the Principle of Population,* agriculture has kept pace with the growing population and rising incomes by increasing its use of natural resources (land and water) and other inputs (energy, fertilizer, and chemicals). During the 1960s there was widespread anxiety that in the face of rapid population growth, serious food shortages and famines were practically inevitable.

Yet aided by "Green Revolution" high-yielding varieties, greater use of fertilizers, investments in irrigation, and expansion of cropland, agricultural production not only kept up with population growth, but also increased available food calories per capita. The result was a gradual decline in the real (inflation-adjusted) price of food. According to the International Monetary Fund food commodity price index, between 1975 and 2005 (i.e., between the last major global food crisis in 1973-1974 and the recent rapid run-up in food prices in 2006-2008), agricultural prices remained essentially unchanged in nominal terms and, after adjusting for general price inflation, declined by about 4 percent per year in real terms. This amounted to a nearly 60-percent reduction in the real price of food commodities over this 30-year period, making food much more affordable for the world's growing population.

Increased food supply and lower food prices, however, have not come without costs to the global environment. Today it is clear that agriculture not only needs to meet rising demand, but also needs to freeze or shrink its environmental footprint. Put simply, the challenge for 21st century agriculture is to do more with less. The world's growing demand for agricultural production must be met not by bringing more land into production, with more gallons of water, or with more intensive use of inputs that impact the environment, but by being better stewards of existing resources through the use of technological innovation combined with policy reforms to ensure proper incentives are in place.

Where Are We Now?

By the 1980s "Green Revolution" technologies had become widely adopted in most developing countries, with the exception of those in sub-Saharan Africa. Perhaps an even more important lesson of the "Green Revolution" was the realization that agricultural research could contribute decisively to spurring agricultural growth. As a result, many countries ramped up their research spending, developing post "Green Revolution" technologies and farming practices that have maintained and even accelerated the rate of productivity growth in agriculture. Many of these new technologies focus on increasing the overall efficiency of inputs. Biotech crops, conservation tillage, drip irrigation, integrated pest management, precision agriculture, and new multiple cropping practices are examples of new technologies that have raised the efficiency and productivity of agricultural resources over the past few decades. There has been an increase in crop yields (output per acres of cropland) and in many countries there has been an increase in output per ton of fertilizer applied, output per liter of water withdrawn for irrigation, and output per farmer – an important factor for poverty alleviation and food security. This greater reliance on increased productivity will have to accelerate to meet the needs of a growing planet by 2050, while limiting agriculture's environmental footprint.

Taken together, gains in the rate of productivity can be best tracked in a measure economists term Total Factor Productivity (TFP) – the output per unit of total resources employed in production. Gains in TFP imply that agricultural production grows without requiring greater use of agricultural resources, at least in the aggregate. It is possible that the use of some kinds of inputs may increase as they substitute for other inputs, such as more mechanization for less labor, without changing aggregate input use. A gain of 1 percent in TFP is equivalent to a 1-percent reduction in the resources required to produce a ton of agricultural output.

Economists have developed estimates of agricultural TFP growth for many countries in the world, especially industrialized countries. Information on agricultural TFP growth in developing countries is spottier. However, a number of recent studies have been published on productivity patterns for major developing countries such as China and Brazil, as well as transition countries of the former Soviet Union and Eastern Europe. The Economic Research Service (ERS) of the U.S. Department of Agriculture has combined these country-specific studies with additional analysis of productivity growth in other regions to construct a global measure of agricultural TFP growth since 1961. This index shows how much of the total growth in agricultural production has been due to expanding resource use (i.e., using more land, labor, fertilizers, etc. in production) and how much has been due to improving TFP.

According to this research, growth in TFP accounts for a steadily rising share of the growth in global agricultural production since the 1960s. During the Green Revolution decades of the 1970s and 1980s, total world output of crops and livestock rose by an average of 2.2 percent per year according to the FAO. ERS estimates show that expanding resource utilization accounted for nearly two-thirds of this growth while rising TFP accounted for the other one-third. From 1990 to 2007, world agricultural output was still growing by just over 2 percent per year, but TFP improvements now accounted for more than 70 percent of this growth.

Rising agricultural TFP substantially reduces the need to bring more natural resources and inputs into production. In some regions of the world, such as in the European Union and the countries of the former Soviet Union, total resources employed in agriculture actually declined. In developing countries, led by China and Brazil, resource utilization in agriculture was still increasing, but at a slower rate than previous decades. At the same time, growth in productivity in these countries had accelerated. By several measures – TFP, crop yield, livestock milk and meat yield, and labor productivity – these countries were closing the gap with developed countries. Some developing countries, however, remained stuck in low and stagnant productivity, most notably those in sub-Saharan Africa.

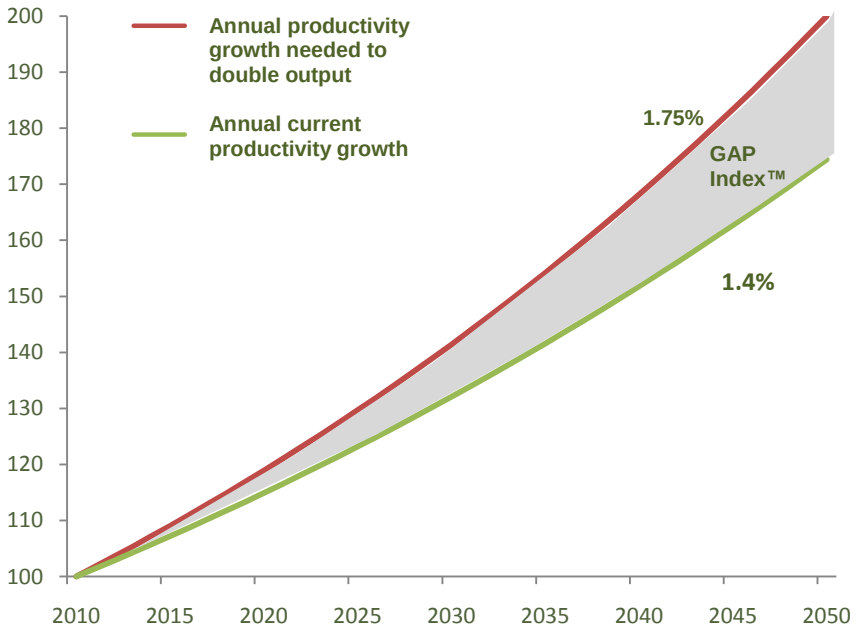
For the world as a whole, agricultural TFP grew by an average of 1.4 percent per year between 2000 and 2007, the last year for which estimates are available. If this productivity growth rate is maintained into the future and if the aggregate agricultural resources available for production do not increase, this is the rate at which world agricultural output would grow. While there are still options to expand such factors of production as agricultural land and labor, these resources are likely to become increasingly constrained in the coming decades. In some parts of the world, the growth of cities is reducing available cropland and diverting water from agriculture. Climate change may further reduce land and water resources available for agricultural production, as well as increase production instability. If the price of natural gas – a key ingredient in the manufacture of nitrogen fertilizer – rises or new mineral sources of potash fertilizer are not discovered, global supplies of inorganic fertilizers could also become increasingly constrained. All of these factors point toward a need to increase agricultural TFP growth.

Closing the GAP

Doubling agricultural output by 2050, while freezing agriculture's environmental footprint, will require growing the TFP to at least 1.75 percent annually from the current 1.4 percent (Figure 3). Not only will we need to raise the average rate of TFP growth by one-fourth above its present rate to close the gap, but also productivity will need to grow even more rapidly during the next two decades, when demand will be increasing faster before leveling off by 2050.

The primary lever for raising TFP growth is by increasing investments in science and technology. But it takes years to reap the benefits of such investments. Moreover, public sector investments in agricultural research and extension in developed and many developing countries have been slackening off in recent years. Not only must this trend be reversed, but also policies that impede the dissemination of new technologies and reduce incentives to farmers to increase their productivity should be reformed. Such policy changes will help raise TFP growth in the near term by enabling more rapid uptake of new technologies while more robust research develops improved technologies for the future. Better coordination between the public and private sectors in agricultural research and development is also needed to raise the research productivity of each sector.

Figure 3. The Global Agricultural Productivity Index™



Source: Farm Foundation, NFP calculations (2010) based on USDA ERS data.

Given the right tools and incentives, the world's agricultural producers and agribusinesses will rise to the challenge of closing the productivity gap. But those incentives and tools are heavily influenced by public policy. In the United States and most developed economies, both public policies and private-sector decisions have been shaped by decades of abundance and declining real food prices. These policies have been primarily focused on buffering producers from the effects of declining real prices for agricultural commodities, while globally the funding for agricultural research has stagnated. While private investment in agricultural research has increased, this investment has been more narrowly focused and the benefits have yet to reach many of the world's producers.

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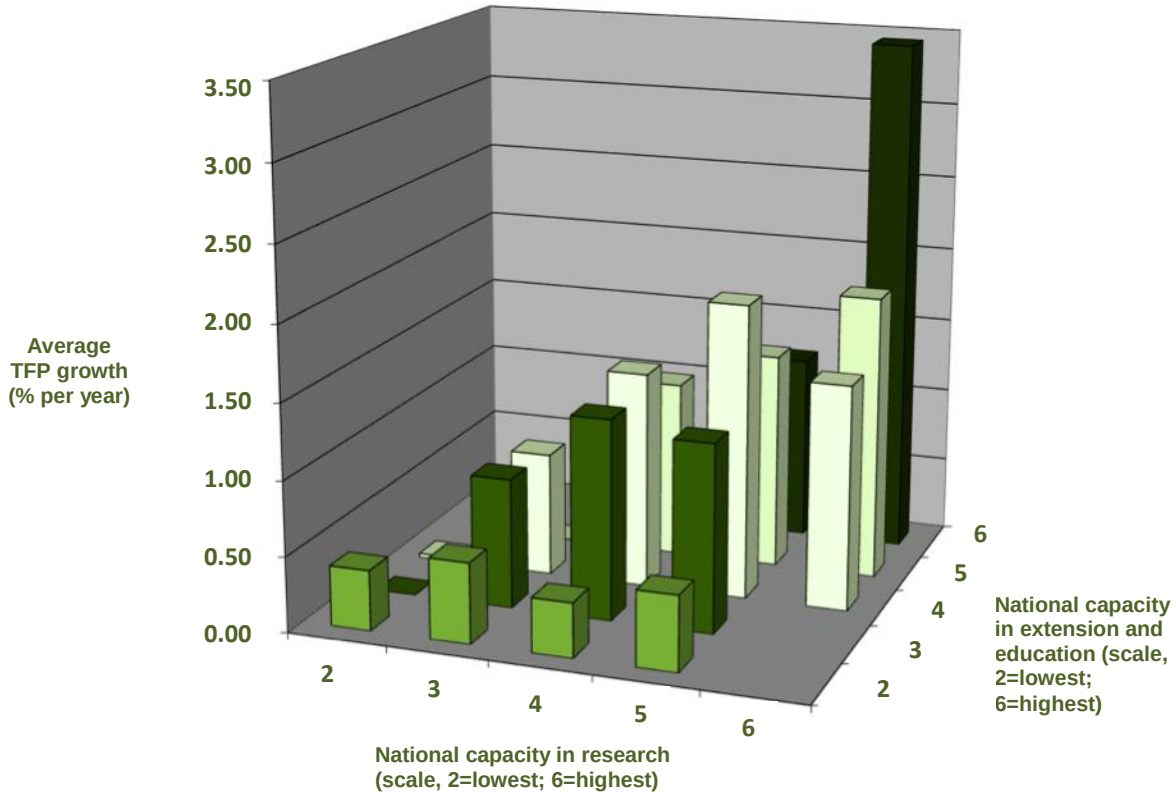
Cross-country comparisons have shown that countries that have made greater investments in "technology capacity" (research, extension, and rural education) have achieved higher agricultural TFP growth rates (Figure 4). But technology capacity and productivity growth continue to vary widely around the world (Figure 5). Closing the gap will require major new investments in technology in both developing and developed countries.

Between 1970 and 2007, some of the countries with the fastest growing TFP were:

- Malaysia 3.1 percent per year
- China 2.5 percent per year
- Brazil 2.4 percent per year

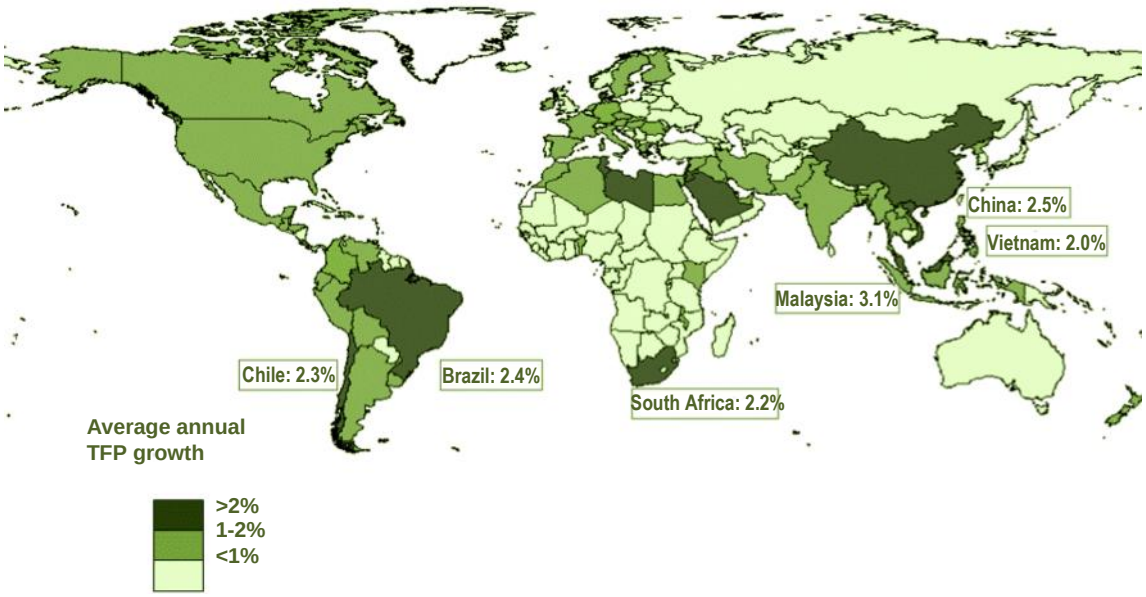
On the other end of the spectrum, the average annual TFP growth rate was only 0.5 percent for developing countries in sub-Saharan Africa and 0.6 percent per year for the countries of the former Soviet Union over this period.

Figure 4. Measures of Agricultural Technology Capacity and Productivity Growth in Developing Countries since 1970



Source: Evenson & Fuglie (2010), USDA ERS.

Figure 5. Average Annual Agricultural TFP Growth Rates by Country, 1970-2007



Source: Fuglie (2010), USDA ERS.

While the development and adoption of new technology is key to raising productivity growth, research alone will not close the gap. Agricultural resources and population are not distributed evenly over the planet. If agricultural production is to take place where it will achieve the greatest level of efficiency and minimize environmental impacts, agricultural and trade policies must be structured to provide appropriate incentives. Closing the gap also means eliminating waste of the crops that farmers grow. In developed countries much of the post-harvest loss occurs at the consumer level. In developing countries, however, post- harvest loss is due to lack of modern storage, transportation, and processing facilities. Closing the gap will mean focusing on productivity not only at the farm level, but also in the entire food system. Significant public and private investments in capital and infrastructure will be required.

An Evergreen Revolution

Simply put, the challenge is on the scale of supporting an “Evergreen Revolution” that is longer in duration and “greener” than the last. It will take innovations like those that spurred the remarkable increases in productivity in the “Green Revolution” of the 1970s and 1980s, which averaged a staggering 2.2 percent growth in output per year. Yet this new “Evergreen Revolution” must endeavor to do more with less, in terms of natural resources and other inputs.

Increasing annual TFP growth from 1.4 percent to 1.75 percent may not seem like a big challenge. However, it takes years to reap the returns of investments in the infrastructure and research required to increase productivity. Failure to begin now could well mean that the gap will not be closed by 2050.

Achieving the goal will require meaningful innovation that leads to heightened, scalable productivity in every facet of agriculture. Central challenges that must be overcome to sustainably meet the world’s demands of agriculture for food, feed, fiber, fuel, and other uses include:

- Dramatically increasing the efficiency of water utilization, including the development of drought-tolerant crops.
- Focusing on sustainable use of croplands.
- Maximizing yields through scientific advancements in cropping and livestock systems.
- Improving nutrient utilization.
- Raising human labor productivity with mechanization.
- Improving utilization of feedstuffs by livestock.
- Improving food system infrastructure and processing to benefit agricultural products distribution and minimize waste.

While great, the challenge is achievable. There is promise. Modern, productive agriculture has many new innovations in the pipeline. However, more must be done. With the right combination of tools and incentives, as well as both public and private sector investments around the globe beginning now, agriculture will be poised to close the global productivity gap and sustainably meet the world's needs in 2050.

The Global Harvest Initiative is dedicated to spurring the development and sharing of agricultural innovations with those that need it most. Members include Archer Daniels Midland Company, Congressional Hunger Center, Conservation International, DuPont, International Conservation Caucus Foundation, John Deere, Monsanto, The Nature Conservancy, TransFarm Africa Corridors Network, and World Wildlife Fund. Further support is welcome from public and private sector entities sharing the goal of closing the global productivity gap.

For more information, visit www.globalharvestinitiative.org.