THE ROLE OF TECHNOLOGY IN AGRICULTURE

BY: THE DU PONT ADVISORY COMMITTEE ON AGRICULTURAL INNOVATION AND PRODUCTIVITY FOR THE 21ST CENTURY

INTRODUCTION

Our current trajectory with food is not sustainable. The world’s population will climb to over 9 billion in the coming years, with nearly all of the growth occurring in less developed parts of the world where agricultural productivity is relatively low, such as Sub-Saharan Africa and Asia.\(^1\) This population boom will be accompanied by increased strains on our food supply and resources, causing increased pressure on already delicate political and ecological systems, as well as threats to global security.

To feed our ballooning population, global food production must increase by an estimated 70 percent, and almost double in developing countries.\(^2\) Moreover, we will need to address both undernutrition and overnutrition, which contribute to poor health outcomes and impose significant costs on our society. As a result, the need has never been greater for innovative solutions that will lead to significant improvements in our food and nutritional security, including greater investment in science and technology.

For years, scientific and technological advancements have benefited farmers in the industrialized world by driving agriculture production. However, smallholder farmers who are responsible for 80 percent of the food in the developing world have yet to see similar gains.\(^3\) These farmers, the majority of whom are women, lack access to many of the tools needed to be successful, such as modern irrigation practices, crop management products, fertilizers, postharvest loss solutions, improved seeds, mobile technology, as well as access to information and extension services.

Through these tools and through much greater investment in agriculture, we can move toward more sustainably curbing global hunger and malnutrition around the world by dramatically increasing productivity yields, conserving food by substantially reducing postharvest losses and food wastage, giving farmers access to real-time information and services in the field, and even

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improving the nutritional content of foods. As a result, broader use of and investment in science-based technologies can enable:

- **Improved livelihoods of farmers and their families by producing more and higher quality crops for a growing population;**

- **Enhanced nutritional value and safety of food to improve the health and wellbeing of people around the world; and**

- **Agriculture sustainability through reduced resource use.**

We must imminently work to meet global food demand through science-based innovation that reaches farmers, particularly smallholder farmers, around the world. Nearly every industry has experienced scientific advancements that have led to profound achievements, and in many cases, have enabled us to solve some of the globe’s biggest challenges. Innovation in the agricultural industry offers a similar promise of improving farmers’ lives, feeding and nourishing more of our population, and consequently, improving the political, ecological, and economic stability of our world.

**BACKGROUND**

By 2050, the world’s population will exceed 9 billion people – a projected growth of more than 30 percent and amounting to an estimated 2.3 billion more people to feed.\(^4\) To put this in perspective, consider that we will need to produce the same amount of food over the next four decades that we produced over the past 8,000 years.\(^5\) And, we already use the equivalent of a planet and a half of resources.\(^6\) Consequently, farmers need access to seeds that use fewer resources and that are better for the environment, as well as other tools and agronomic practices that enable us to produce more with less.

We face other obstacles as well. The food system of the future will look different than it does today. People are increasingly moving away from where food is grown and are less aware of how it is grown. By 2050, an estimated 70 percent of people will be living in urban areas,

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creating the need for processing and storage technology, sound infrastructure, efficient distribution channels, and open trade policies. The uneven distribution of arable land around the globe means that farmers will need to freely and efficiently move food and access markets to be successful. And, climate change and increasing weather volatility will drive demand for new seed technology adapted for harsher conditions and stressed land.

However, there are many barriers impeding the adoption of these tools, including a lack of uniform and consistent regulatory frameworks and intellectual property protections, the inability of smallholder farmers to access financing and capital to invest in technology that will improve their yields, as well as a general lack of understanding of the positive role that science and technology can play in agriculture and food.

Despite these challenges, agricultural technology has played a central role in overcoming food security challenges in the past. The 20th Century marked a time of significant public investments in scientific research that contributed to historical increases in food production. Coined the Green Revolution, Norman Borlaug’s discoveries contributed to historical increases in food production during a time of widespread hunger and malnutrition. For example, the adoption of high-yielding varieties of rice and wheat, the expansion of irrigation infrastructure, and the use of other inputs more than doubled cereal production in Asia between 1970 and 1995. As yields increased, farmers quickly adopted these technologies, resulting in increased profitability and incomes. By 1995, real per capita income nearly doubled in Asia and poverty declined from nearly three out of every five to less than one in three.

Meeting global food needs will demand another era of widespread adoption of innovative science-based solutions, but one that addresses vastly more complex issues and improves upon the Green Revolution, including environmental and ecological considerations, nutrient deficiencies, and food wastage. We must approach the challenges of this century in a comprehensive way, mindful of the value and limitations of each of the tools available to us. If the world is to produce the amount of food necessary to feed more than 9 billion people in a way that considers nutritional needs and resource scarcity, that enables us to grow food in the face of

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9 Id.

10 Id.
global climate change, and that improves the livelihoods of farmers globally, the adoption of technological advancements in our food and agricultural system is necessary to achieve that goal.

**THE PROMISE OF SCIENCE-BASED SOLUTIONS**

Science-based agricultural tools hold great promise for tackling the world’s growing population and food demands. From improved seeds, to modern crop protection solutions, to mobile technology for farmers in the fields, to making foods fresher, safer, and healthier along the food chain, the agricultural and food system of the future can be more productive, more sustainable, more efficient, and more interconnected. Greater investment in and broader adoption of science and technology can enable the world to meet the growing demand for food as the population increases by (1) improving the livelihoods of farmers and their families by producing more and higher quality crops for a growing population; (2) enhancing the nutritional value and safety of food to improve the health and wellbeing of people around the world; and (3) contributing to agriculture sustainability through reduced resource use.

**Improving the Livelihoods of Farmers and their Families by Producing More and Higher Quality Crops for a Growing Population**

Closing the current gap in agricultural productivity will require a significant increase in agricultural yields around the world. This will require seeds that enable crops to withstand environmental and biological stresses, crop protection solutions, modern irrigation practices, mobile technology, fertilizer, and mechanization.

**Plant Breeding**

Plant breeding, the science of optimizing a plant’s genetic makeup to produce desired characteristics, can be accomplished through a number of techniques, including hybridization and more complex molecular techniques. Through plant breeding techniques, we can produce higher yielding crops that are better in quality, tolerant to environmental pressures, resistant to pests and diseases, and tolerant to insecticides and herbicides.

**Hybridization**

Hybridization is a tool that farmers have used to develop high-yielding seeds since the early 1900s.\(^{11}\) Hybridization involves crossing two or more crop lines to produce hybrid crops with more favorable traits, resulting from combining genes from the selected parents. Compared to

open-pollinated varieties, hybrid seeds, when combined with plant breeding techniques, can increase some crop yields by as much as 50 to 100 percent, and provide more tolerance to diseases, pests, and environmental stresses.

Since the introduction of hybrid corn in the U.S., farmers around the world have increasingly planted hybrid seeds, including corn, sorghum, canola, sunflower, and rice, because of its ability to produce higher yielding, stronger crops. Today, approximately 95 percent of all corn grown in the U.S. is from hybrid seed and hybrid seeds are sold in nearly 70 countries around the world.

**Molecular Marker-Assisted Selection**

Molecular markers are small sequence differences between various lines in a plant breeding population that can be used, when physically linked to traits, as a surrogate for the presence or absence of a desired trait without having to field test for the attributes of that trait. Molecular markers are detected through DNA sequencing methods using DNA derived from plant samples. The practice of molecular marker-assisted selection enables plant breeders to combine desirable plant traits rapidly and in large numbers. Through this technique, breeders can reduce the time it takes to develop some new crop varieties. Additionally, it increases the efficiency of plant breeding by enabling breeders to genetically pre-screen multitudes of potential varieties with high precision prior to selecting lines or hybrids with the highest genetic potential for costly field evaluation.

Consequently, this technique is an increasingly common breeding technique in crops where marker systems have been developed and marker-trait associations have been established. Genetic markers are also being used to monitor and increase genetic diversity in breeding programs. Diversified crop varieties protect farmers, including smallholders in food insecure countries, from being vulnerable to widespread disease and environmental stresses that impact certain varieties.

**Agricultural Biotechnology**

Plant breeders use agricultural biotechnology as another source of genetic variation to produce superior crops with improved yields, while requiring fewer inputs. The products of this technology have been widely used by farmers for over a decade in varieties of corn, cotton, soybeans, and canola. Biotechnology expands the genes available for crop improvement beyond those present in the breeding populations and uses the tools of genetic transformation to bring specific genes to the genetic makeup of the plant. To date, this method has been used to enable crops to tolerate insects, viral diseases, certain herbicides, produce grain with improved nutritional quality, and resist stresses caused by extreme weather.
These desired characteristics result in significant productivity gains. During 2011, over 16 million farmers in 29 countries chose to plant 160 million hectares of biotechnology crops. Ninety percent, or 15 million of those farmers, were small resource-poor farmers in developing countries. And, in 2010 alone, the economic benefits from biotechnology crops for developing countries reached $7.7 billion in U.S. dollars.

Despite the promise of this technology, European governments and some non-governmental organizations (NGOs) have been less open to embracing biotechnology’s benefits. While this sentiment is diminishing due in part to input from European scientists, it has had a broader influence on the developing world. While embraced in much of Latin America, other countries in the developing world have been less willing to adopt these technologies, impacting the ability of farmers, particularly smallholders, to access the tools needed to increase yields and improve their livelihoods.

**Crop Protection Solutions**

Advances in crop protection have been a powerful tool in combating the pests, diseases, and weeds that can be devastating to crop yields. In total, food crops compete with tens of thousands of species of weeds, nematodes, and plant-eating insects. As a result, even with crop protection products, 20 to 40 percent of food crops are lost each year to pests. These losses occur not only in the fields, but during storage and in the home.

Through the use of crop protection products, which include chemical (e.g., insecticides, fungicides, and herbicides) and non-chemical tools (e.g., biological pest control and barrier-based approaches), farmers have significantly curbed these losses and increased their productivity yields. These tools enable farmers to produce more crops with less land, making them critical to ensuring a reliable food supply.

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13 Id.

14 Id.


16 Id.

17 CropLife America, Crop Protection Facts and Pesticide Data, available at http://www.croplifeamerica.org/crop-protection/pesticide-facts; CropLife Africa Middle East, 10 Pesticide Facts
Other Technologies

Beyond improved seeds and crop protection tools, other technologies enable farmers to increase their productivity, such as modern irrigation practices, mobile technology, fertilizer, and mechanization. Over the years, irrigated land has proven to be twice as productive as rainfed farmland.\(^\text{18}\) This will be particularly important in the coming decades given that an estimated 1.8 billion people will live in water scarce regions by 2025.\(^\text{19}\)

Similarly, mobile technology can enable farmers to increase their yields by connecting them through text messages and help lines to agricultural market information, best practices, and extension services designed to meet their localized needs.\(^\text{20}\) Fertilizers have also contributed to doubling and tripling crop yields, supplying crops with the essential nutrients missing from soil, as well as facilitating the more efficient use of land and water.\(^\text{21}\) And, with advances in mechanization, farmers can more efficiently tend to their crops and produce more with less manpower. Today, farmers are even using precision farming solutions, such as global positioning system (GPS) technology, to increase yields while using fewer inputs, leading to estimated productivity gains of 10 percent and an average input savings of 15 percent.\(^\text{22}\)

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\(^{18}\) FAO, Water and Food Security, available at [http://www.fao.org/docrep/x0262e/x0262e01.htm](http://www.fao.org/docrep/x0262e/x0262e01.htm).


Enhancing the Nutritional Value and Safety of Food to Improve the Health and Wellbeing of People Around the World

Technological advancements in food and agriculture are making it possible to improve the health and wellbeing of millions of people worldwide. Malnutrition, defined as both undernutrition and overnutrition, impacts roughly 1 billion men, women, and children. Approximately one in seven people go to bed hungry worldwide\textsuperscript{23} and undernutrition is linked to the deaths of one out of every three children under the age of five in the developing world\textsuperscript{24} Meanwhile, in 2008, over 1.4 billion adults were overweight or obese and an estimated 65 percent of the world’s population lives in countries where overnutrition takes more lives than undernutrition.\textsuperscript{25}

Consequently, a critical component of global food security will be ensuring not only the production of more calories, but enhancing the nutritional content and health profile of the food the world consumes. As people increasingly migrate to urban areas and away from where food is grown, fortifying processed food will be particularly important.

In regions of severe undernutrition, such as Sub-Saharan Africa and South Asia, innovative public-private partnerships are being used to increase the nutritional content of food through the biofortification of indigenous crops. In Kenya and Nigeria, the Bill & Melinda Gates Foundation is supporting the Donald Danforth Plant Science Center and partners to develop cassava varieties through biofortification that will be higher in beta carotene, which the body converts to vitamin A, protein, and iron. The Global Alliance for Improved Nutrition (GAIN) has taken on the fortification of foods and condiments, such as maize, flour, sugar, soy sauce, and vegetable oil in 19 countries with vitamin and mineral deficiencies.\textsuperscript{26} Through these programs, neural tube defects fell by 30 percent after folic acid was incorporated into maize meal and wheat flour in South Africa.\textsuperscript{27} In China, data has shown that anemia was reduced by an estimated one-third following the fortification of soy sauce with iron. Enriching these staples and other indigenous crops will save and improve the lives of millions of children and adults.\textsuperscript{28}

\textsuperscript{23} UN, WFP, Hunger Stats, available at \url{http://www.wfp.org/hunger/stats}.

\textsuperscript{24} UN, WFP, Nutrition, available at \url{http://www.wfp.org/nutrition}.

\textsuperscript{25} WHO, Obesity and Overweight Fact Sheet (May 2012), available at \url{http://www.who.int/mediacentre/factsheets/fs311/en/index.html}.

\textsuperscript{26} Global Alliance for Improved Nutrition (GAIN), GAIN National Food Fortification Program, available at \url{http://www.gainhealth.org/programs/gain-national-food-fortification-program}.

\textsuperscript{27} \textit{Id.}

\textsuperscript{28} \textit{Id.}
Foods can also be made healthier through the incorporation of ingredient solutions such as proteins, fibers, and cultures providing, for example, cardiovascular and digestive health benefits. In addition, food manufacturers are able to reduce the fat, sugar, caloric, and salt content of foods with the use of enabling ingredients such as emulsifiers, stabilizers, and reduced-calorie sweeteners. It is also possible to increase the fiber and phytonutrient content of food through enzyme processing. Science and technology can lead to ingredient solutions that have the potential to impact both undernourishment and the increasing rates of obesity and diabetes worldwide.

Beyond making the food we eat better, advances in science enable us to preserve foods longer, improving food safety. Nearly one third of the world’s food – approximately 1.3 billion tons – is lost or wasted each year. In the developing world, a third of food is lost at the production, harvest, post-harvest, and processing phases due to a lack of adequate storage and processing facilities. By contrast, one-third of food in developed countries is wasted by retailers and consumers at the table and in the refrigerator. However, through natural and bio-based ingredients, such as enzymes, cultures, plant extracts, and new preservation techniques, we can reduce food wastage and spoilage significantly in regions without adequate storage and processing facilities, as well as extend the shelf life of food wasted in the industrialized world. For example, emulsifiers and enzymes can be added to bread to keep it fresh for several more days and protective cultures can be added to dairy products to allow them to withstand elevated temperatures and humidity.

Contributing to Agriculture Sustainability through Reduced Resource Use

Agriculture’s footprint on our ecosystem is substantial. In fact, agriculture consumes 70 percent of our world’s water for the irrigation of crops. However, advancements in agriculture technology are an important contributor to a more sustainable agriculture system that promotes continuous improvement and less resource use. Scientists are developing seeds that are better adapted for volatile climates and that are drought resistant, as well as technology that uses less water and improves upon modern irrigation practices. Investment in agricultural innovation is necessary to enable the world to produce more food with fewer resources and less land.


Already, agricultural biotechnology has led to reductions in fossil fuel use, soil tillage, water runoff, and pesticides, all of which are critical to sustainable agriculture. Through more targeted crop protection products, farmers are able to reduce pesticide applications by significant amounts. From 1996 to 2009, global pesticide applications decreased by nearly 9 percent, eliminating 867 million pounds of pesticide applications. Agriculture technology, such as herbicide resistant crops, has also driven the adoption of no-till farming, resulting in improved soil health and conservation, decreased soil erosion, and decreased herbicide runoff. On average, no-till agriculture results in 70 percent less herbicide runoff, 93 percent less erosion, and 69 percent less water runoff.

Greenhouse gas emissions are also improved through advances in agriculture technology. No-till farming allows for less agricultural machinery on fields, which results in a substantial reduction in greenhouse gas emissions. As a result, no-till farming has led to a reduction in the carbon footprint of crops by reducing the use of diesel fuel in tending to these crops while increasing the amount of carbon maintained in the soil. In 2009, these crops contributed to a reduction of 39 billion pounds of carbon dioxide, equaling the removal of 7.8 million cars from the roads in one year.

There is also the opportunity for more efficient livestock production. The impact of livestock production on resource use and the environment will grow as the consumption of meat, milk, and egg products increases. Feed ingredients, such as feed enzymes, direct-fed microbials, and silage inoculants can all contribute to improved efficiency of converting cereals, legumes, or forage to meat, milk, and egg products and in reducing the associated output of nitrogen and phosphorus into the environment. Plant-based proteins will be needed as a less resource intensive human


33 Id. at 5.

34 Id. at 28.

35 Id. at 29.

36 Id.
food protein source as the population grows and the demand for meat, milk, and egg products increases along with rising incomes, especially in developing countries.

**EMBRACING SCIENCE-BASED TECHNOLOGIES**

While technology has a pivotal role to play in achieving global food security, overcoming barriers to acceptance remains difficult. Given the magnitude of our challenge, the global community must think beyond single solution approaches to feeding the world and give farmers the choice and access to all the tools that can boost productivity safely and sustainably. Realizing that no tool will be perfect, agricultural technology provides one of the best opportunities to address world hunger. It will be critical to engage in meaningful stakeholder dialogue on the challenges and benefits of technology and the variety of tools available, on the gaps we face and what tools and investments are needed, and the way in which regions can foster an environment that unleashes innovation.

**Stakeholder Dialogue and Partnerships**

Meeting global food demand will require innovative partnerships and an open and collaborative dialogue among stakeholders. The global community should build upon the common goal of tackling world hunger and malnutrition and move beyond disagreements about whether any one tool is best to get there, because no single tool will solve a problem of this magnitude. It will take new partnerships between the public and private sector, NGOs, governments, and the development community that drive a broad spectrum of advancements in agriculture and nutrition.

**All Tools on the Table**

Farmers know what is best for them and their land, and should have the ability to choose the tools and technologies that are right for them and the markets they serve, whether it be organic practices using conventionally bred varieties, hybrid seeds, or biotechnology. Typically, farmers want access to the tools and technologies that will provide them with the best chance of increased yields and success. When given the choice and the financing tools for investment, farmers often choose science-based agricultural technology, such as higher-yielding crop varieties as an alternative to saving seeds each year.

In the U.S. alone, 80 percent of corn, 92 percent of soybeans, and 86 percent of cotton planted are biotechnology varieties.\(^{37}\) Other countries, such as China, Argentina, India, Canada, and

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Brazil have similarly embraced science-based technologies. Moreover, in every country where improved crop varieties have been planted, farmers increased their incomes – in 2009, by as much as $10.8 billion worldwide.\textsuperscript{38} Farmers deserve the opportunity to embrace any one of the available agricultural tools and practices to meet the food demands of their families, communities, and the world.

\textit{An Environment that Unleashes Innovation}

Finally, the global community must create an environment that unleashes innovation to improve agriculture globally. The investment required to bring agricultural technology products to market is substantial. For biotechnology products, development to approval takes anywhere from twelve to twenty years and up to $150 million for each product. Similarly, crop protection products can take as long as ten years and up to $250 million. Consequently, private sector investment in innovative technologies requires policies and science-based regulatory frameworks that support technology adoption, as well as strong intellectual property protections.

Other factors also play a role in agriculture investment. Governance practices influence the ability of organizations to invest in improved agriculture in developing regions. Infrastructure, such as roads, bridges, ports, and railways, is also essential for farmers to be successful and for private sector investment. In addition, the availability of financing, capital, and insurance enable farmers to make longer term investments in their land. Finally, local governments must invest in their own agriculture sectors to contribute to the success of their farmers. The commitment of governments in developing nations will be key to bring science-based tools to the smallholder farmers who need them most.

\textbf{CONCLUSION}

As with any crisis of our time, world hunger and malnutrition will require the efforts of all stakeholders. Through increased collaboration and partnerships, we can leverage the resources, expertise, and tools of the collective whole. The Green Revolution demonstrated the potential for science to bring countries from famine to a surplus of food. The world must again embrace collective innovation to achieve global food and nutrition security. We will need to support the full array of innovative solutions that are available to farmers, including agricultural biotechnology, to meet global food demand.


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The DuPont Advisory Committee on Agriculture Innovation and Productivity represents a group of experts in global agriculture development, science, policy, and economics. Established by DuPont in 2010, the Committee includes former Senator Tom Daschle, who serves as chair, and Charlotte Hebebrand, Chief Executive of the International Food & Trade Policy Council; J.B. Penn, Chief Economist for Deere & Co.; Pedro Sanchez, Director of the Tropical Agricultural and the Rural Environment Program and Director of the Millennium Villages Project at the Earth Institute; and Jo Luck, former President and CEO of Heifer International.