Global Harvest
INITIATIVE

2015 GAP Report®

GLOBAL AGRICULTURAL PRODUCTIVITY REPORT®

2015 Global Agricultural Productivity Report® (GAP Report®)
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Global Harvest
INITIATIVE

The Global Harvest Initiative (GHI) was formed in 2009 by companies that advocate collaborative solutions to meet the rising demand for food and agricultural products through sustainable innovation as world population climbs to over 9.7 billion by 2050. We serve as a private-sector policy voice for productivity growth throughout the agricultural value chain, advancing technologies and practices that conserve natural resources, adapt to and help mitigate climate change and improve people's livelihoods, nutrition and living conditions. Our current members are DuPont, Elanco Animal Health, John Deere, Monsanto Company, The Mosaic Company and Novozymes.

We are joined by consultative partners who share their knowledge and experience in agriculture, conservation, nutrition and the needs of small-scale farmers. Our consultative partners include 9b Group, ACDI/VOCA, Congressional Hunger Center (CHC), Conservation International, Farm Foundation, Global Alliance for Improved Nutrition (GAIN), Inter-American Development Bank (IDB), Inter-American Institute for Cooperation in Agriculture (IICA), Purdue University School of Agriculture, The Nature Conservancy, New Markets Lab/TransFarm Africa, Robert B. Daugherty Water for Food Institute and World Wildlife Fund.

MEMBERS

DuPont – The miracles of science™
Elanco
John Deere
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Mosaic
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CONSULTATIVE PARTNERS

9b group
ACDI/VOCA – Expanding Opportunities Worldwide
Congressional Hunger Center
Conservation International
Farm Foundation
gain – Global Alliance for Improved Nutrition
IDB
IICA
Purdue Agriculture
The Nature Conservancy – Protecting nature. Preserving life.
NML – New Markets Lab
Water for Food – Robert B. Daugherty Institute, University of Nebraska
WWF

BUILDING SUSTAINABLE BREADBASKETS

Declaring that eradicating poverty and hunger is both the "greatest global challenge and an indispensable requirement for sustainable development," United Nations member states in September 2015 adopted the Sustainable Development Goals (SDGs), an ambitious agenda to end hunger and poverty once and for all by 2030. The SDGs are designed to protect the planet, to preserve natural resources and to create the conditions necessary for sustainable and inclusive economic growth and prosperity. The Global Harvest Initiative (GHI) applauds and supports this cooperative effort of governments, multilateral institutions and civil society.

In the spirit of the SDGs, the Global Harvest Initiative is delighted to present our **2015 Global Agricultural Productivity Report® (GAP Report®): Building Sustainable Breadbaskets**.

A vibrant agriculture and food sector is a powerful foundation for broad-based, inclusive economic growth and development, creating multiplier effects throughout the entire economy. In addition to those employed directly in agriculture and food production, manufacturing, marketing and sales, there are many others who provide training, financial services, energy, technology, equipment and transportation, adding value to and creating jobs in all economic sectors. With the right policies, innovations and knowledge-based practices, agriculture systems provide sufficient, nutritious and affordable food, conserve natural resources, raise people out of poverty, empower women and girls and generate sustainable economic growth across a variety of industries. Scientific and technological advancements improve productivity, reduce the environmental footprint of food production and help mitigate its contribution to climate change.

Our 2015 GAP Report® **highlights the impressive legacy of the United States' conservation agriculture system**, which was built in the wake of the 1930s Dust Bowl crisis and created a vibrant agricultural economy and abundant food supply. It demonstrates that threats can be overcome, but continued commitment and investment are necessary to generate new innovations to conserve soil, water and other precious natural resources, assuring that we are maintaining a sustainable breadbasket for tomorrow's challenges. The report also **shines a spotlight on Zambia**, a country that is diversifying its agricultural production systems and building its capacity to become a regional breadbasket in southern Africa.

Tackling global hunger and ensuring future generations have access to sufficient affordable and nutritious food in the face of population growth and climate change requires immediate attention from public and private sectors alike. Together we must create food and agriculture systems that incorporate transparency, best practices of productivity, conservation, animal well-being and responsible stewardship, from farmer to consumer, building resilience at every step of the value chain.

This should be our shared vision of agriculture; we should settle for nothing less.

Margaret M. Zeigler

Dr. Margaret M. Zeigler
Executive Director
Global Harvest Initiative

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THE GLOBAL AGRICULTURAL IMPERATIVE

Together we must nearly double global agricultural output by 2050 to respond to a rapidly growing population and to meet the consumer demands of an expanding middle class.[1]

How will we be able to produce the food, feed, fiber and fuel the world is going to need at mid-century — and do it sustainably?

2015
WORLD POPULATION
7.3 billion

2050
WORLD POPULATION
9.7 billion

By 2050, the world's population will increase from 7.3 billion in 2015 to 9.7 billion.[2]

More than half of this growth will occur in Africa.[3]

Urban areas will grow by more than 2.5 billion people — half the world is urban now, and two-thirds urban by 2050.[4] The world's rural population will decline, reducing labor available in rural areas for growing food.

2015
GLOBAL MIDDLE CLASS
50%

2050
GLOBAL MIDDLE CLASS
70%

The global middle class will increase from 50% to **70% by 2050**; most of this growth will take place in developing countries.[5] More consumers will be able to afford more expensive foods, creating **a consumer-driven food, feed, fiber and fuel demand revolution.**

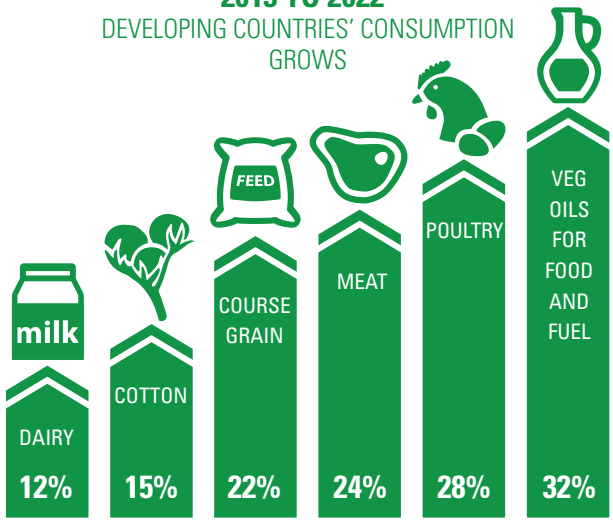
2013 TO 2022[6]
ANNUAL PER CAPITA INCOME GROWTH

1.7%
DEVELOPED COUNTRY

4.4%
DEVELOPING COUNTRY

Between 2013 and 2022, developing country annual per capita income will grow 4.4% versus 1.7% in developed countries, resulting in **high demand for meat, crops, fiber and fuel.**

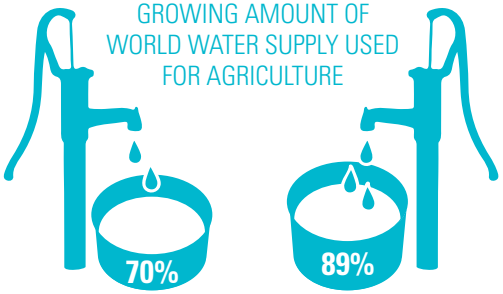
2013 TO 2022[7]
DEVELOPING COUNTRIES' CONSUMPTION GROWS



Demand for agricultural products in developing countries outpaces local production and creates a gap that must be filled with trade.[8]

Doubling agriculture output to meet this growing demand and achieve food security, if not done sustainably by conserving the environment, will increase pressure on natural resources and thereby threaten global capacity to produce.

2015 TO 2050
GROWING AMOUNT OF WORLD WATER SUPPLY USED FOR AGRICULTURE



2015 **2050**

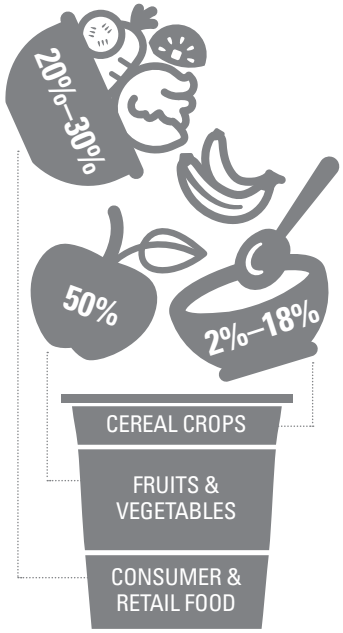
Water: 70% of the water extracted from the world's rivers, lakes and aquifers is used for agriculture and this will rise to **89%** by 2050. In developing countries, irrigation **already uses 85%** of extracted water.[9]

Soil: 37% of the world's land is presently used for crops and pasture.[10] Expanding land for agriculture reduces biodiversity, increases soil erosion and releases stored carbon from soil, contributing to greenhouse gas emission.

Livestock production: Ruminants (cattle and sheep) will emit more methane without technology and practices that can reduce emissions.

Food Waste:
2 to 18% of post-harvest cereal crops and **up to 50%** of fruits and vegetables are lost in developing countries, depending on country, season or product.[11, 12]

20 to 30% of total food supply in developed countries is wasted at the retail and consumer level.[13]

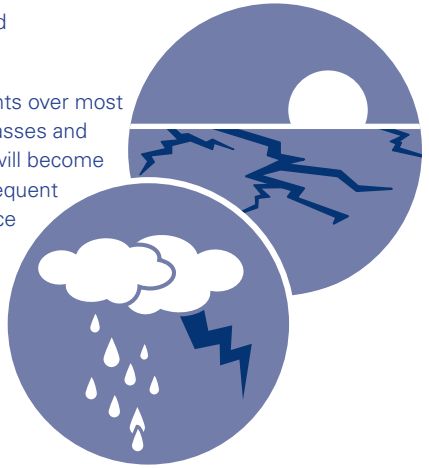


Climate change and weather variability will fundamentally alter global food production patterns.[14]

Changing rainfall patterns and higher nighttime temperatures will require adaptation practices in low latitude and tropical regions but may benefit high latitude regions.[15]

Climate change may reduce renewable surface water and groundwater in most dry subtropical regions, intensifying competition for water.[16]

Extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will become more intense and more frequent as the world's mean surface temperature increases, posing risks for crop and livestock production.[17]

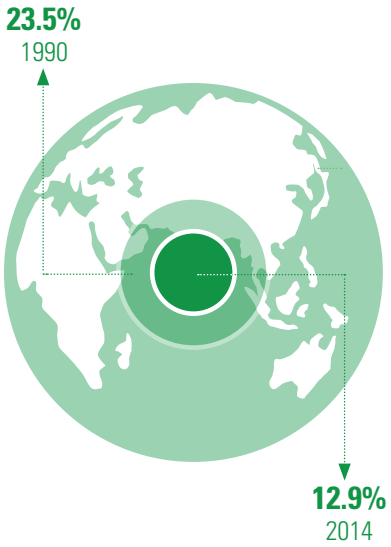


Meeting nutritional needs requires increasing

the availability, affordability and consumption of nutrient-rich foods across all regions of the world.

GOOD NEWS[18, 19]

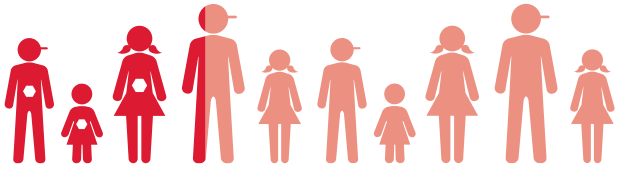
GLOBAL PROPORTION OF UNDERNOURISHED DECREASED



The world has made **progress in reducing** the proportion of **undernourished people** since 1990.

BAD NEWS[19]

BOTH HUNGER AND OBESITY IMPACT HEALTH

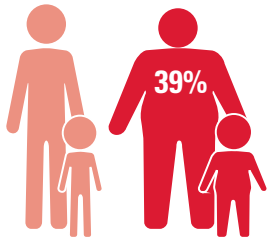


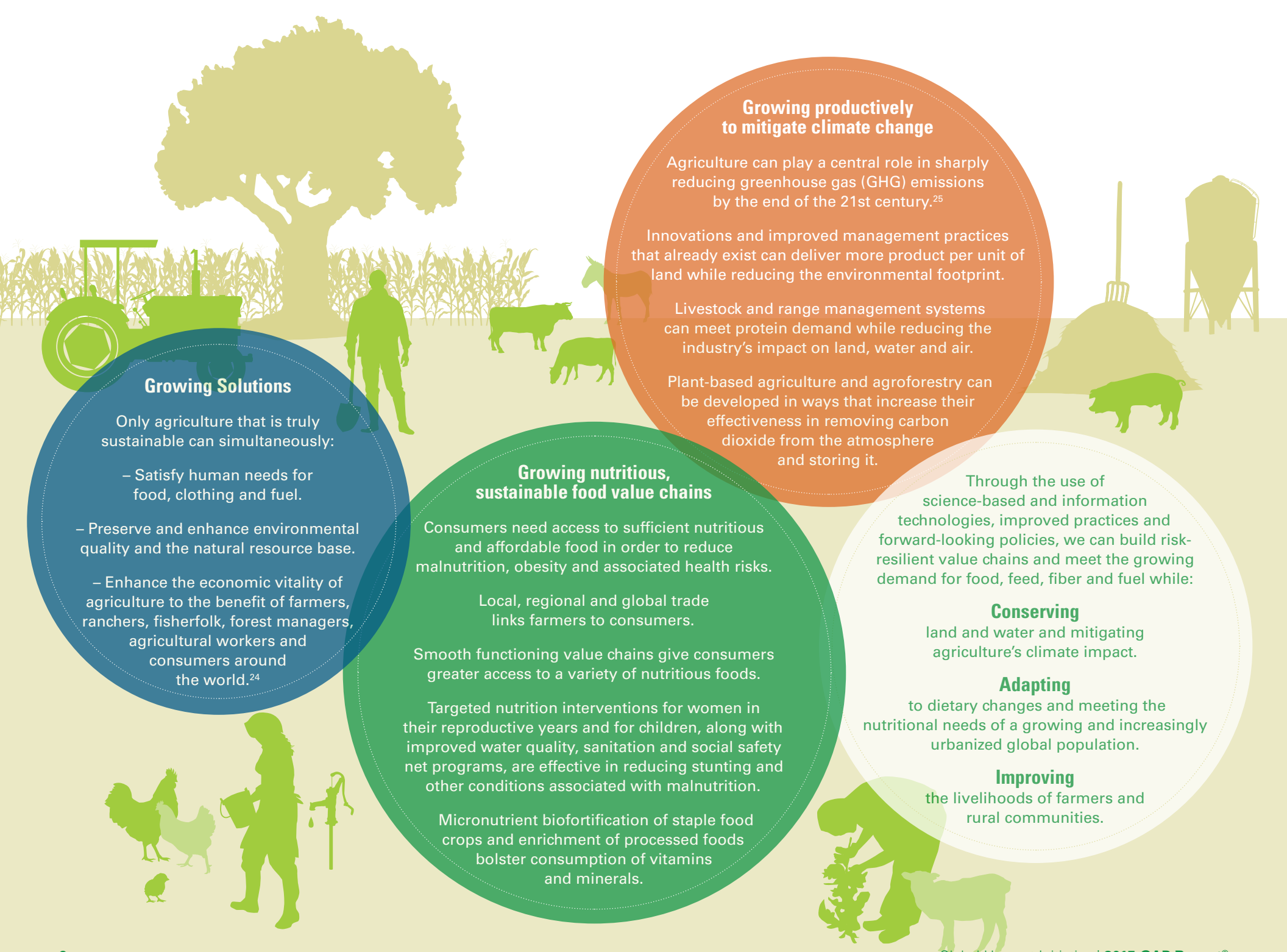
1/3 of children today suffer from hunger or some form of nutrient deficiency.[20]

165 million children around the world are stunted, or too short for their age, with permanent cognitive and physical impairment.[21]

Childhood **obesity is increasing rapidly in developing countries,** with a rate of increase more than 30% higher than that of developed countries.[22]

Proportion of the world's adults who are **overweight** is now 39%, nearly doubling since 1980.[23]





Growing Solutions

Only agriculture that is truly sustainable can simultaneously:

– Satisfy human needs for food, clothing and fuel.

– Preserve and enhance environmental quality and the natural resource base.

– Enhance the economic vitality of agriculture to the benefit of farmers, ranchers, fisherfolk, forest managers, agricultural workers and consumers around the world.[24]

Growing productively to mitigate climate change

Agriculture can play a central role in sharply reducing greenhouse gas (GHG) emissions by the end of the 21st century.[25]

Innovations and improved management practices that already exist can deliver more product per unit of land while reducing the environmental footprint.

Livestock and range management systems can meet protein demand while reducing the industry's impact on land, water and air.

Plant-based agriculture and agroforestry can be developed in ways that increase their effectiveness in removing carbon dioxide from the atmosphere and storing it.

Growing nutritious, sustainable food value chains

Consumers need access to sufficient nutritious and affordable food in order to reduce malnutrition, obesity and associated health risks.

Local, regional and global trade links farmers to consumers.

Smooth functioning value chains give consumers greater access to a variety of nutritious foods.

Targeted nutrition interventions for women in their reproductive years and for children, along with improved water quality, sanitation and social safety net programs, are effective in reducing stunting and other conditions associated with malnutrition.

Micronutrient biofortification of staple food crops and enrichment of processed foods bolster consumption of vitamins and minerals.

Through the use of science-based and information technologies, improved practices and forward-looking policies, we can build risk-resilient value chains and meet the growing demand for food, feed, fiber and fuel while:

Conserving
land and water and mitigating agriculture's climate impact.

Adapting
to dietary changes and meeting the nutritional needs of a growing and increasingly urbanized global population.

Improving
the livelihoods of farmers and rural communities.

THE CRITICAL IMPORTANCE OF BOOSTING AGRICULTURAL PRODUCTIVITY

Efficiently producing more agricultural product, and wasting less as product moves from field to consumer, requires the adoption of conservation practices and precise use of inputs. In the face of growing demand for food, environmental constraints and a changing climate, adoption of science-based and information technologies, reuse of waste products and good stewardship of land, water and other natural resources have become even more critical. **Enhancing and accelerating sustainable agricultural productivity is a therefore a central component of a comprehensive strategy to meet the rising demands of a growing world.**

Productivity growth — a measure of output per unit of input — allows more to be produced while maximizing the use and impact of scarce resources. Productivity growth is a major determinant of economic expansion and vital for promoting an improved standard of living. In the agricultural context, productivity growth, by lowering production costs per unit of output, can reduce commodity prices for consumers and free land, labor, capital and other inputs for use elsewhere in the economy.

This year's GAP Report® highlights how farmers and producers in every region of the world — from commercial farmers in the United States and other developed countries to smallholder farmers in Zambia and other developing countries — can and must be part of the solution.

TOTAL FACTOR PRODUCTIVITY: A DATA-DRIVEN MEASURE OF PROGRESS

Assessing the potential for greater productivity requires the collection and analysis of input and output data in a systematic manner over time, creating valid and reliable records that can be used to measure changes ▸▸

A COMPREHENSIVE STRATEGY TO FEED THE WORLD IN 2050

Accelerating agricultural productivity growth is a necessary, but not sufficient, component of achieving food and nutrition security. FAO estimates that one-third of food produced is lost or wasted along the pathway from production to human consumption.[26] Just like poor production practices, waste and loss of agricultural outputs has an environmental impact. In addition, 795 million people today are not able to regularly access and consume sufficient food to meet their basic needs, setting back their chances, and their children's chances, for leading healthy, productive lives.[27]

A comprehensive global food security strategy requires that governments, civil society organizations and private sector companies join together and contribute their special talents and knowledge to address the underlying causes of hunger and malnutrition. Public-private partnerships generate new opportunities to use the world's vast agricultural and food systems more effectively to deliver affordable, nutritious foods to all people. Governments, civil society and business can work together to strengthen and coordinate programs that improve incomes, diets, sanitation and hygiene for vulnerable populations.

Meeting the rising demand for food in a sustainable way creates a virtuous feedback loop — conserving resources while improving nutrition and generating new economic opportunity, particularly if small-scale producers throughout the world are given sufficient support and access to productive assets such as land, finance, risk management services and innovation technology.

in productivity overall as well as the changes in underlying factors that contribute to productivity. Agricultural productivity is often described in terms of yield, such as output per hectare of crops or gallons of milk per dairy cow. However, yield alone is an incomplete measure of productivity. We must also know the amount of inputs used per unit of output in order to calculate total productivity, since yield can be boosted by adding such factors as machinery and labor, or by increasing applications of crop protection products and fertilizer and feed.

Depending on local needs and conditions, farmers may use a range of strategies to increase their production yields:

Expansion — Using more land or extending irrigation to cropland so that it can be harvested more frequently and protected against drought;

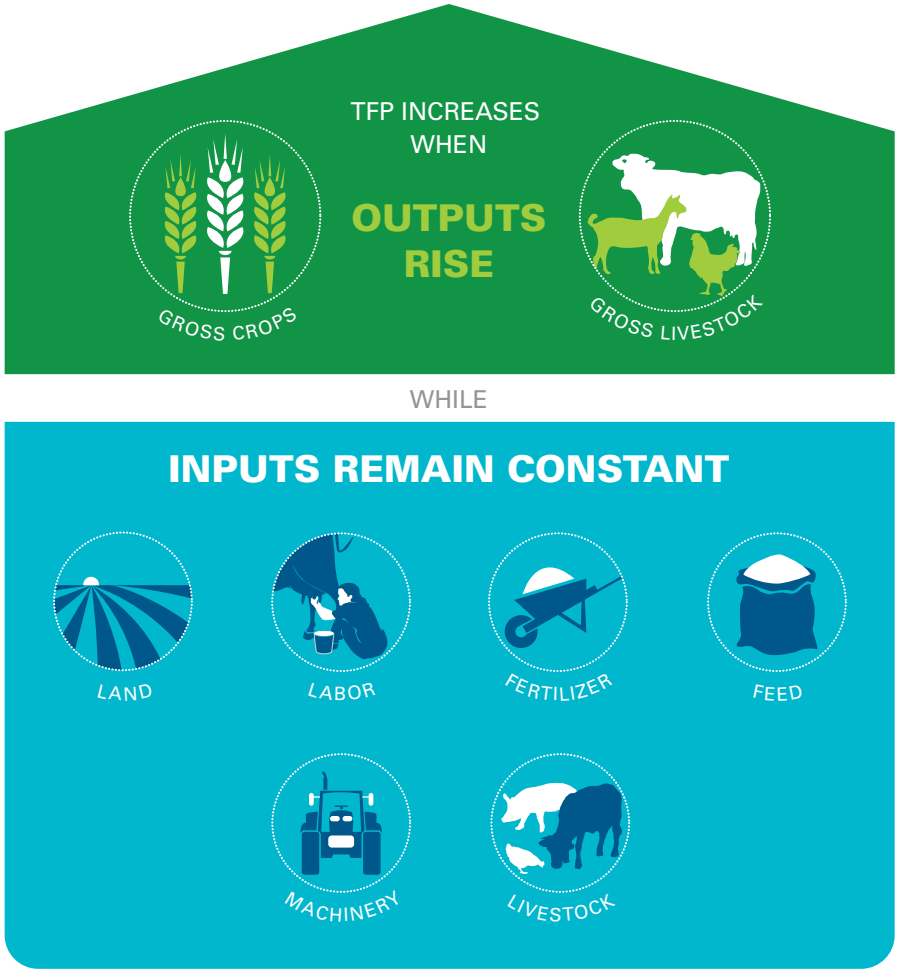
Intensification — Increasing application of fertilizer, machinery, labor or other inputs on land used to grow crops or raise livestock; or,

Efficiency — Adopting technologies and farming practices that result in more output from existing resources, measured by **total factor productivity (TFP)**.

TFP is the ratio of agricultural outputs (gross crop and livestock output) to inputs (land, labor, fertilizer, feed, machinery and livestock). TFP measures changes in the efficiency with which all inputs are transformed into outputs: as farmers use inputs more precisely and efficiently, or adopt improved cultivation and livestock rearing practices, their output grows while using the same or even reduced amount of inputs (Figure 1).

For crops, improved TFP results from higher yielding, disease resistant and drought or flood tolerant crop varieties, more efficient and timely cultivation and/or harvesting practices, or using technologies and data to indicate precisely when and how much water, fertilizer and crop protection to apply. In animal production, TFP grows when breeding stock is selected for more favorable genetic qualities and when livestock receive better husbandry, health care and high quality feeds that deliver more nutrition per volume.

Figure 1: Total Factor Productivity



Governments, farmers and agribusinesses are not just interested in whether agricultural output is growing — they want to know whether increased output growth is due to **better use of existing resources and application of improved products and technologies.** Examining Total Factor Productivity (TFP) is the best way to get that information, which can be enormously useful in identifying where improvements are needed in agricultural systems and can be used to guide policy and investment decisions.

TFP GLOBAL TRENDS

The development and adoption of advanced hybrid wheat and rice crop technologies in developing countries in the 1960s by Dr. Norman Borlaug and other plant breeders marked the start of an agricultural growth era known as the global Green Revolution (a process already well underway in North America, Western Europe and Japan). A suite of practices accompanied the adoption of the higher yielding crops: increased irrigation and expansion of fertilizer use and crop protection products such as pesticides. This resulted in higher yields through intensification in the 1960s and 1970s.

But thanks to continuing agricultural research and development efforts of global institutions such as the CGIAR (Consultative Group on International Agricultural Research), national agricultural research centers such as land-grant colleges and universities in the United States and EMBRAPA in Brazil, as well as private sector innovation, more precise and sustainable agricultural practices began to emerge in the 1980s.

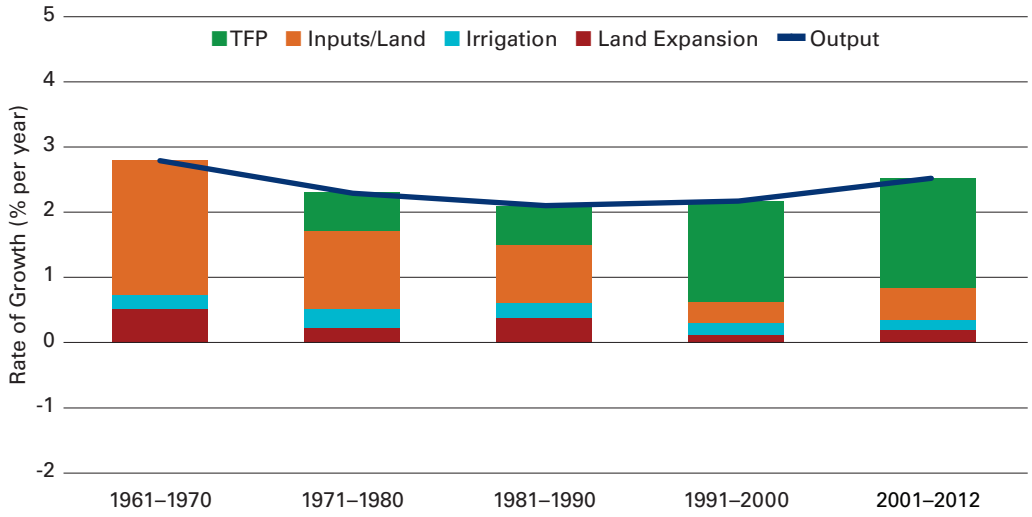
Livestock and crop genetic advancements, better nutrition and feed for animals, improved machinery and farm equipment and more efficient water use technologies — led by private sector research and innovation — are now accelerating productivity as measured by TFP (Figure 2). High-yielding varieties were also developed for a wide range of crops, including maize, oilseeds and root crops.

More recently, the combination of advanced data systems and information technologies is allowing even greater accuracy in choosing and applying inputs and helping farmers conserve resources and adapt to changes in weather patterns.

For the following figures, sources of agricultural output growth are:

- **TFP** — Gross amount of crop and livestock outputs per inputs (labor, capital and materials)
- **Inputs/Land** — Gross amount of fertilizer, machinery, feed, labor and other inputs per hectare of agricultural land
- **Irrigation** — Extension of irrigation to agricultural land (which raises the number of crop harvests per year as well as yield per harvest)
- **Land Expansion** — Opening up additional land resources to extend production

Figure 2: Sources of Growth in Global Agricultural Output, 1961–2012



Source: Economic Research Service (2015).

TFP VARIATION BY INCOME

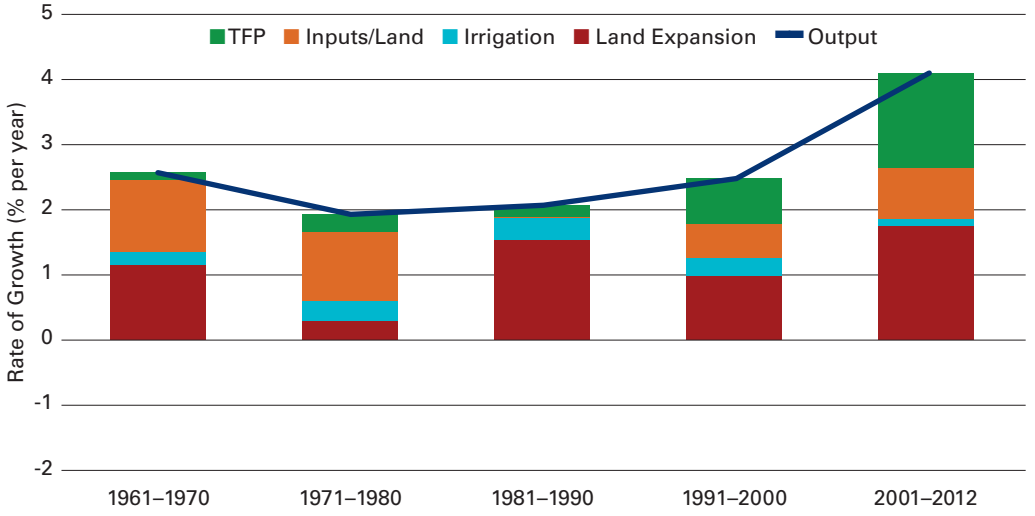
While Figure 2 indicates that TFP is a larger share of agricultural output globally in recent decades, Figures 3 and 4 show there is considerable variation across countries, particularly when considering per capita income and development levels.[28]

Low-income countries have boosted their agricultural output dramatically since the mid-1980s, and a growing share of their agricultural output is now attributable to TFP, or more efficient production (Figure 3). Nonetheless, a significant share of their agricultural output is still from intensification of input use. Raising productivity in low-income countries will require increasing and sustaining investments in agricultural research and development, more effective extension services, expansion of rural infrastructure and value chain development.

To achieve this goal, low-income countries must place agriculture at the center of their policy agendas, incorporating climate-smart and resilient approaches, and reforming policies to encourage adoption of innovations and investments from the private sector. Support from the international community, including joint research, technology transfer, and building capacity of local communities, institutions and business, will ensure that agricultural growth and better nutrition is widespread and inclusive. Public-private partnerships can be tailored to target investments to meet the special needs of smallholder farmers, women, cooperatives and producer associations.

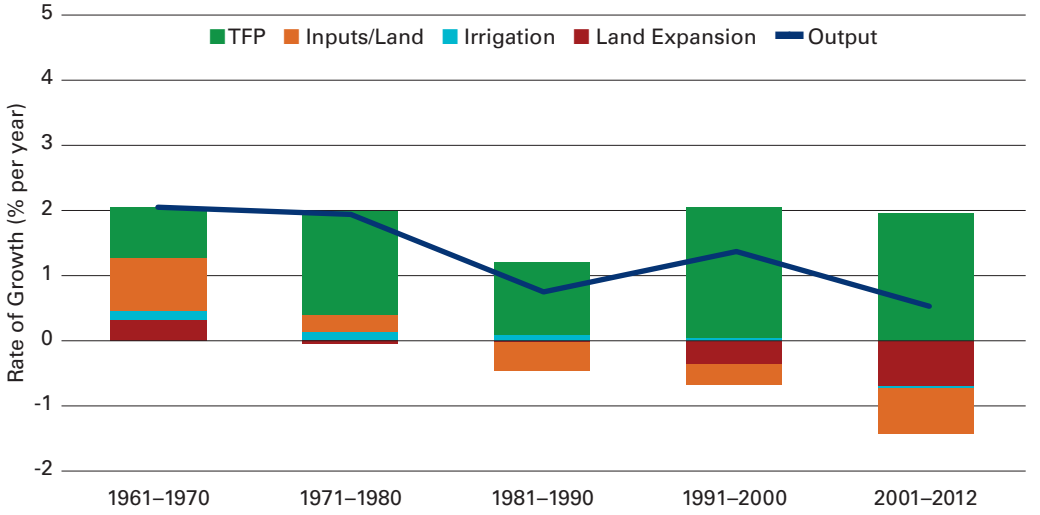
In high-income countries, decades of public and private investments in agricultural research and development, extension services and rural infrastructure, along with adoption of innovations in crop and livestock genetics, have made TFP the principal source of growth in agricultural output (Figure 4). Use of land in agriculture has declined, allowing land to be placed into conservation, forestry or recreation use. Nevertheless, overall agricultural output growth has slowed markedly in high income countries, along with a decline in the rate of growth of TFP. With new technologies on the horizon, such as more widely available precision agriculture and data systems to support farmers, this trend can be reversed.

Figure 3: Sources of Growth in Agricultural Output: Low-Income Countries, 1961–2012



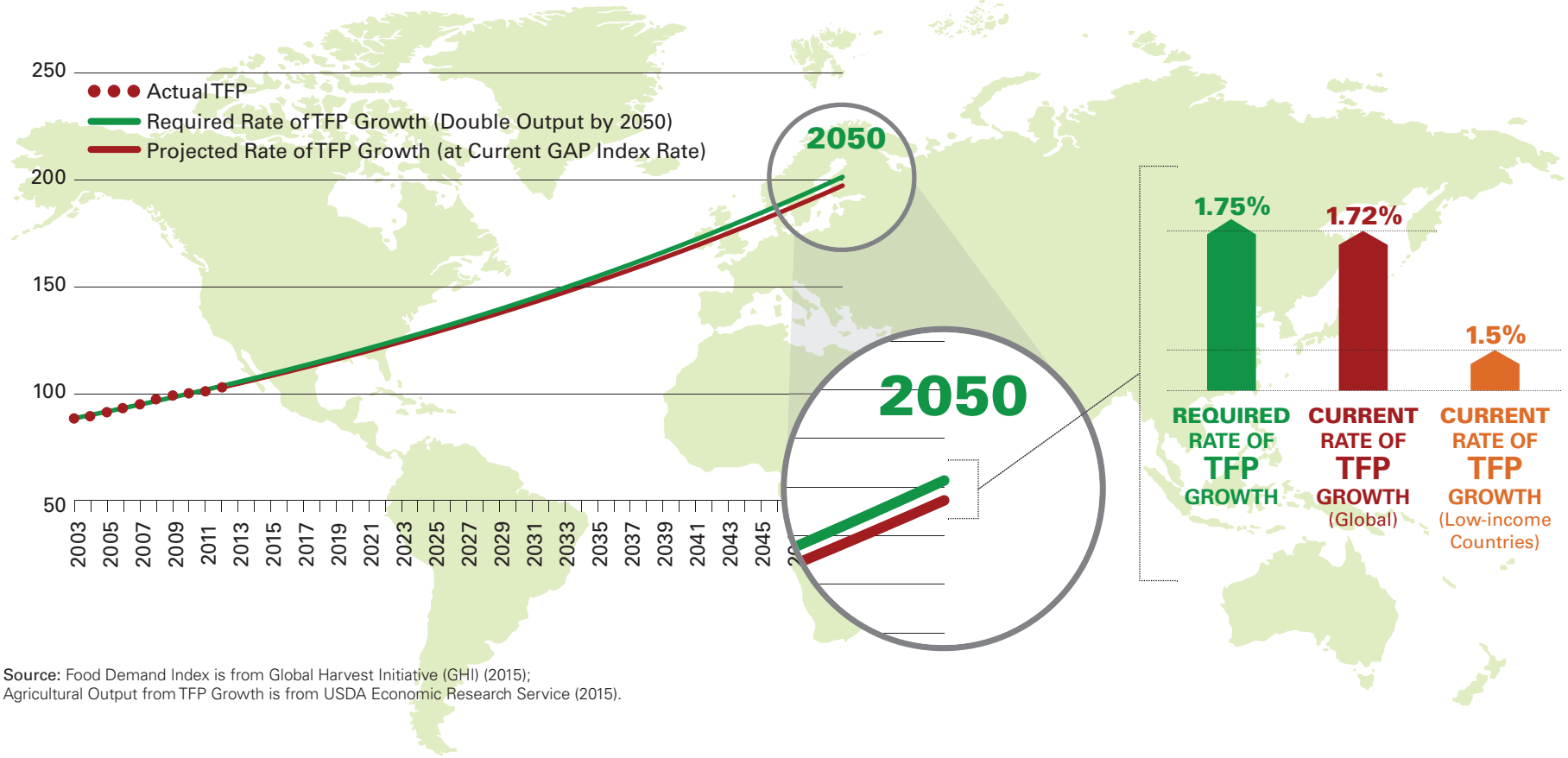
Source: Economic Research Service (2015).

Figure 4: Sources of Growth in Agricultural Output: High-Income Countries, 1961–2012



Source: Economic Research Service (2015).

THE GLOBAL AGRICULTURAL PRODUCTIVITY (GAP) INDEX™



Source: Food Demand Index is from Global Harvest Initiative (GHI) (2015);
Agricultural Output from TFP Growth is from USDA Economic Research Service (2015).

THE GAP INDEX™

In 2010, GHI calculated that global agricultural TFP must grow by an average rate of at least 1.75 percent annually in order to double agricultural output through productivity gains by 2050. While output of food, feed, fiber and fuel will most likely continue to rise in coming decades to keep up with growing global demand, experts are concerned that this production will come at the expense of the environment and natural resource base. Proven practices and technologies, if adopted more widely, can be part of a solution to accelerate global agricultural productivity in sustainable ways that actually reduce agriculture's overall impact on soil, forests and water resources.

Global TFP growth is not accelerating fast enough to double agricultural output by 2050. The U.S. Department of Agriculture's Economic Research Service estimates that since 2003, TFP growth globally has been rising by an average annual rate of only **1.72 percent.** While this growth rate is close to the target, a troubling trend is that for the most recent decade, **TFP growth has been stagnating in the lowest income countries at only 1.5 percent**. The impact of this productivity gap for low-income, food-deficit countries (where population is also growing rapidly) will place great strain on their resource base and may lead to price spikes, as these countries lack the income to import enough food to meet the needs of their citizens.

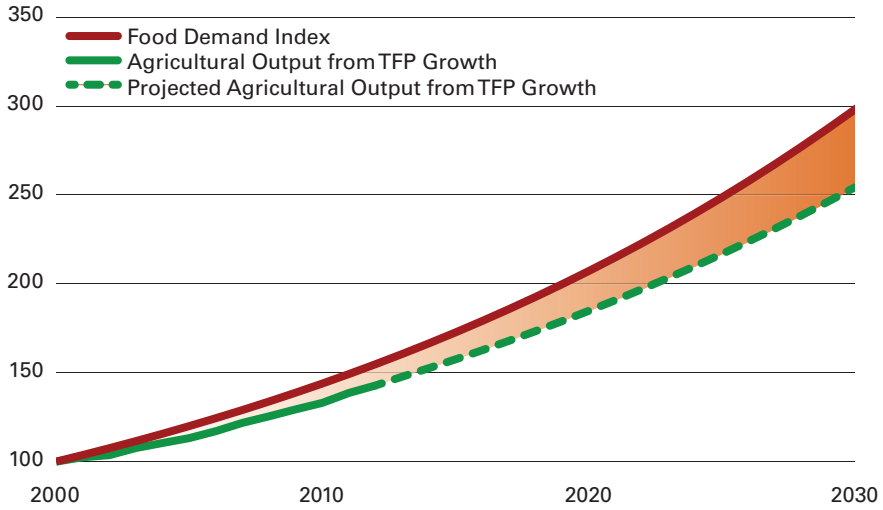
Poor urban households will bear the brunt of higher food prices in these countries, but it will also impact rural populations, since they are net food buyers. The lack of productivity growth may lead to accelerated farmland expansion, opening up fragile tropical forests and increasing loss of wildlife habitat and biodiversity, as well as competition for use of existing water resources.

SPOTLIGHT ON REGIONAL PRODUCTIVITY GAPS

Regional differences in productivity growth illustrate why even a small falloff in the global rate of productivity growth requires immediate attention. In the 2012 GAP Report®, GHI established a series of regional estimates comparing food demand indexes against projected agricultural output from TFP growth, for the period 2000 to 2030. Figures 5 through 8 update these estimates for East Asia, South and Southeast Asia, Sub-Saharan Africa and the Latin America/Caribbean regions.

Each region, with the exception of Latin America/Caribbean, shows insufficient growth in TFP to meet estimated future food and agricultural demand through efficiency. If current trends continue to 2030, the gap in East Asia will be 22 percent; in South and Southeast Asia, 26 percent; and in Sub-Saharan Africa, 86 percent. Countries in these regions will need to prioritize investments in agricultural productivity, as well as increase imports to meet their growing food demands.

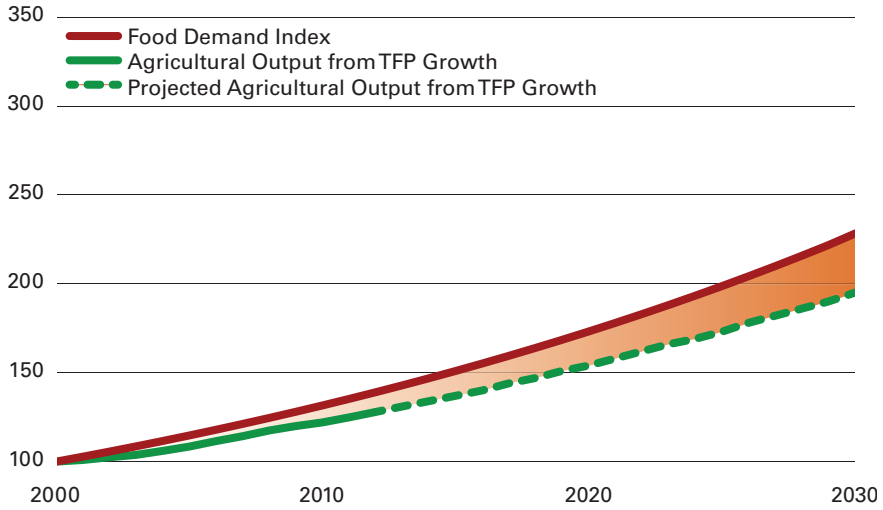
Figure 5: Food Demand Compared to Agricultural Output from TFP Growth in **East Asia**, 2000–2030



78% of total East Asia demand can be met by maintaining the current TFP growth rate.

Source: Food Demand Index is from Global Harvest Initiative (GHI 2015); Agricultural Output from TFP Growth is from Economic Research Service (2015).

Figure 6: Food Demand Compared to Agricultural Output from TFP Growth in **South and Southeast Asia**, 2000–2030



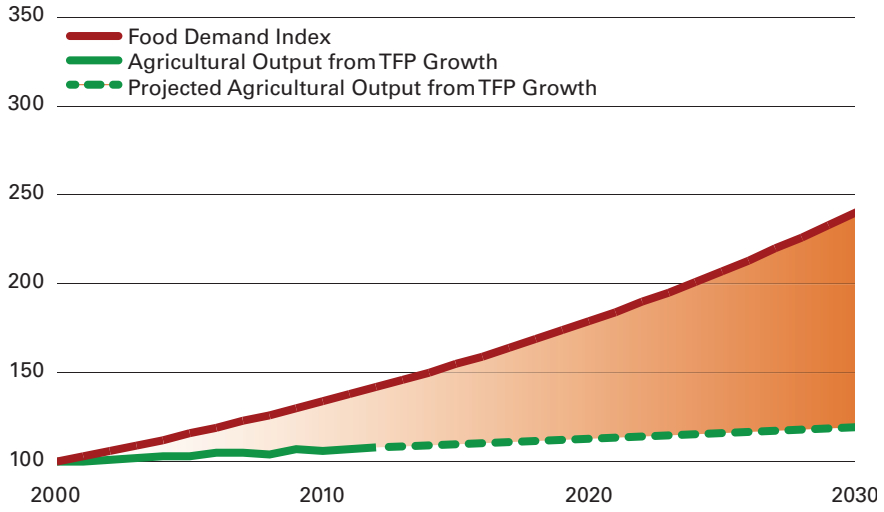
74% of total South and Southeast Asia demand can be met by maintaining the current TFP growth rate.

Source: Food Demand Index is from Global Harvest Initiative (GHI 2015); Agricultural Output from TFP Growth is from Economic Research Service (2015).

Note on methodology: The projection of agricultural output from TFP growth uses USDA Economic Research Services (2015) estimates of average TFP growth during 2003-2012 and assumes this is maintained through 2030. The projected growth in food demand uses UN estimates of population, PricewaterhouseCoopers LLP (PwC) estimates of GDP growth, and estimates of the income elasticity of food demand from Tweeten and Thompson (2008). The income elasticity of food demand indicates the share of the growth in per capita income that will be spent on food. Multiplying the income elasticity by the growth rate in per capita income gives the growth rate in per capita food consumption holding food prices fixed. Adding this to the population growth gives the total growth in food demand for a given price level.

The role of trade will be critical in closing the gap between areas of high food and agriculture demand and those areas that are able to supply more food, feed, fiber and fuel most efficiently. Continual improvements in global and regional supply chains and greater harmonization of trade rules will assure that countries have access to the agricultural goods they need at lower prices. The Latin American region, and particularly the southern cone nations of Argentina, Brazil, Paraguay and Uruguay (ABPU), comprise the largest net exporting zone of agriculture products on the planet.[29] Latin American countries have the potential to vastly increase their response to global demand for food and other agricultural products.[30] The potential is also immense for Sub-Saharan Africa to improve its productivity and reduce the growing food deficit of this region. **The agricultural breadbasket potential of Zambia is explored further in this GAP Report® on pages 52–73.**

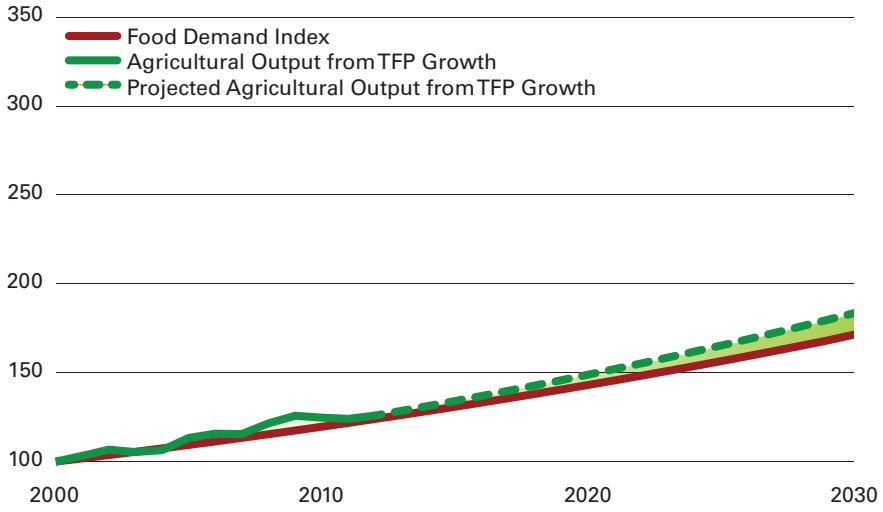
Figure 7: Food Demand Compared to Agricultural Output from TFP Growth in **Sub-Saharan Africa**, 2000–2030



14% of total Sub-Saharan Africa demand can be met by maintaining the current TFP growth rate.

Source: Food Demand Index is from Global Harvest Initiative (GHI 2015); Agricultural Output from TFP Growth is from Economic Research Service (2015).

Figure 8: Food Demand Compared to Agricultural Output from TFP Growth in **Latin America/Caribbean**, 2000–2030



117% of total Latin America/Caribbean demand can be met by maintaining the current TFP growth rate.

Source: Food Demand Index is from Global Harvest Initiative (GHI 2015); Agricultural Output from TFP Growth is from Economic Research Service (2015).

BUILDING BLOCKS FOR SUSTAINABLE BREADBASKETS — FIVE STRATEGIC POLICY GOALS

GHI and its partners have identified **five strategic policy goals** that are the essential building blocks for a more resilient and sustainable agriculture and food system. A long-term commitment to advance these policies is needed to improve agricultural productivity, increase the availability of nutritious food to more people at affordable prices, conserve natural resources, mitigate climate impact and reduce waste and loss.

Invest in public agricultural research, development and extension.

Investment in agricultural research and development (R&D) is a principal driver of agricultural productivity growth. Agricultural R&D investments have long gestation periods: typically it takes more than a decade to realize the full benefits of research and development activities that are in progress today. But, given time, these investments pay high dividends, from higher profits for farmers to more abundant food supply at lower cost for consumers, along with higher social returns, including greater opportunity and a higher quality of life in rural communities. Commitments to public research are also important to reducing the talent gap and filling the pipeline for the next generation of agricultural scientists.

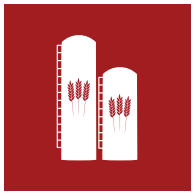
Countries that have built national agricultural research systems (NARS) that are capable of producing a steady stream of new technologies suitable for local farming systems have generally achieved higher growth rates in agricultural TFP than those countries that are not doing this. Developing countries must prioritize and increase investments, as their R&D spending remains much lower as a percentage of agricultural GDP than those of developed, higher income countries. For their part, developed countries should maintain, and increase where necessary, their commitments to public agricultural R&D, spurring innovative partnerships between scientists from government, academia and the private sector and development of technologies that will advance sustainable agriculture on a global scale.

Embrace science-based and information technologies — and scale up efforts to get them in the hands of farmers.

Following scientific principles ensures a methodological approach to the development and improvement of technologies that are critical to sustainably feeding 9.7 billion people by 2050 and must be adopted along the entire agricultural value chain. For farmers, tested technologies are available that can dramatically boost productivity while reducing their impact on the natural resource base and shrinking the

amount of loss and waste of agricultural products. Such technologies can be customized for local use and applied through public and private extension services. Access to technological advancements is particularly important to improve farming and agribusiness in low-income countries, where agriculture employs high percentages of the workforce and accounts for 29 percent of the GDP.[31]

Beneficial technologies are important for farmers of all types and scales and include improved plant and animal breeding, access to biotechnology to enhance the nutrient value and drought tolerance of crops, advancements in animal nutrition and disease management, efficient irrigation and cultivation practices, mechanization to increase productivity and reduce the physical stress of manual cultivation, and post-harvest technologies to reduce loss and improve food quality and safety. Information technologies and mobile phones can provide even small-scale producers with low-cost access to vital information and notifications on planting, weather, pests and market prices.



Enhance private sector involvement in agriculture and infrastructure development.

A critical issue to meet future productivity needs is how to attract the capital investments required for buildings, machinery and equipment, farm improvements, and transport and rural infrastructure. Globally there is a need for almost $80 billion annually in investments[32] to meet these needs. Governments must continue to invest in infrastructure, and must also encourage innovative public and private partnerships for upgrades and improvements. Transparency and coordination is needed between the public and private sectors, starting at the early stages of development, to attract such capital investments.

Remove barriers to regional and global agricultural trade.

Expanding regional and global agricultural trade systems is essential for assuring free flow of agricultural goods and services across regions, creating the opportunity to move food from areas of surplus to those with unmet demand. An enabling environment for trade includes transparent policies and consistently enforced laws and regulations, as well as harmonized trade rules across nations.

Nowhere is this more important than in the developing world, where infrastructure will be key to improving access to vital farming inputs, reducing post-harvest food losses and connecting farmers with markets and fair prices for their products. GHI advocates trade policy that is forward-looking and innovative so that farmers of all scales may take advantage of market opportunities.

Strengthen and coordinate international development assistance and productive safety nets for nutrition.

Developing countries need support and partnership to invest in and implement agricultural development plans and to enhance productivity. Developing country governments will need to leverage and coordinate partnerships with private sector investors, nongovernment organizations and bilateral and multilateral development agencies to transfer technology, build local capacity and make other improvements in local agricultural sectors. Country-led efforts that emphasize sustainable practices, monitoring results and open data policies must be continued and strengthened with international support.

Development assistance for agriculture increased from 2008 through 2010, primarily as a result of $22 billion in new combined commitments made by the G-8 (Group of Eight) and the European Union at the Summit in L'Aquila, Italy in the wake of the global food price crisis. The United States, through its Feed the Future initiative, has met its L'Aquila commitment and continues to foster partnerships with the private sector through the New Alliance for Food Security and Nutrition and through policy innovation and partnerships via the Millennium Challenge Corporation (MCC). Other countries that have kept their L'Aquila commitments include Australia, Canada, Germany, Italy, the Netherlands, Russia, Spain, Sweden and the U.K.

CULTIVATING RESILIENT FOOD AND AGRICULTURE SYSTEMS IN THE USA

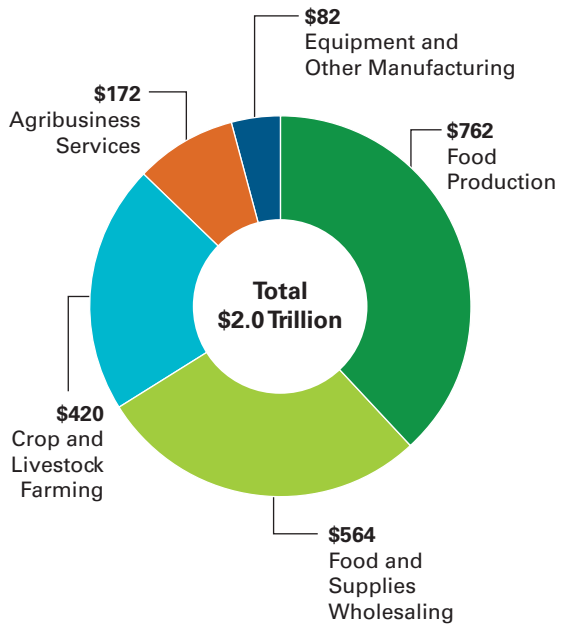
Today the agriculture and food system of the United States is the most abundant, varied and productive in world history. Using diverse methods, U.S. farmers produce crops and livestock in many different terrains and climates, including conventional, organic, identity-preserved (IP) and genetically engineered (GE) production systems, while providing for a wide array of consumer preferences.

With a vast range of domestic and imported fresh, processed and prepared foods and highly efficient supply chains, 321 million consumers in the United States have year-round access to an enormous variety of safe, nutritious and affordable foods.

Over the past 100 years, the U.S. agriculture and food system has evolved through scientific research and improved technologies, fostered by government initiatives, private sector investment and ingenuity throughout the value chain. Agriculture has long supplied food, animal feed, fiber for cloth and fuel for energy, but new advances have increased efficiency and added new products. Biofuels are used to power engines, renewable plastics are produced from plants, and naturally-occurring enzymes and microorganisms are harnessed to enhance soils, improve plant nutrient absorption and protect crops from pests and diseases.

Agriculture is a key driver of U.S. economic growth, providing $2 trillion in revenue and $130 billion in profit for more than 2.6 million businesses. It represents 9 percent of all U.S. exports, totaling $176 billion, and is one of the few economic sectors that enjoys a positive trade balance.[33] The agriculture sector includes crop and livestock farming, food processors and manufacturers, wholesalers and retailers, input suppliers, support services and specialized equipment and technology.

Figure 9: U.S. Agribusiness Revenue, 2015 ($ billion)



Source: www.ibisworld.com.

The industry **employs 19 million people in full and part-time jobs, 9 percent of total U.S. employment in 2013**. On-farm employment provided more than 2.6 million of these jobs. Food services and restaurants and bars accounted for the largest share, 11.1 million jobs.[34]

A GLOBAL AGRICULTURAL POWERHOUSE[35]

Using nutrient-rich feed ingredients, the United States has the **largest fed cattle industry** in the world **and is also the world's largest producer of beef**, primarily high-quality products for both domestic consumption and export.

Livestock and poultry account for over half of U.S. agricultural cash receipts, often exceeding $100 billion per year.

Milk is produced in all 50 states, with the major producing states in the West and North.

Dairy farms, overwhelmingly family-owned and managed, are generally members of producer cooperatives. Dairy products range from cheese, fluid milks, yogurt, butter and ice cream to dry or condensed milk and whey products.

The U.S. vegetable and pulse sector generates about $17.4 billion annually, or 14 percent of U.S. crop cash receipts. **This quantity was generated on less than 2 percent of all U.S. harvested acreage**. California and Florida produce the largest selection and quantity of fresh vegetables.

The U.S. poultry industry is the world's largest producer. It is the second-largest exporter of poultry meat and a major egg producer, with almost 18 percent of total poultry production exported. The poultry and egg industry is a major user of **feed grains**.

The U.S. ranks third in global cotton production behind China and India. Cotton accounts for 35 percent of total world fiber. **The U.S. is the leading cotton exporter**, accounting for over one-third of global trade in raw cotton.

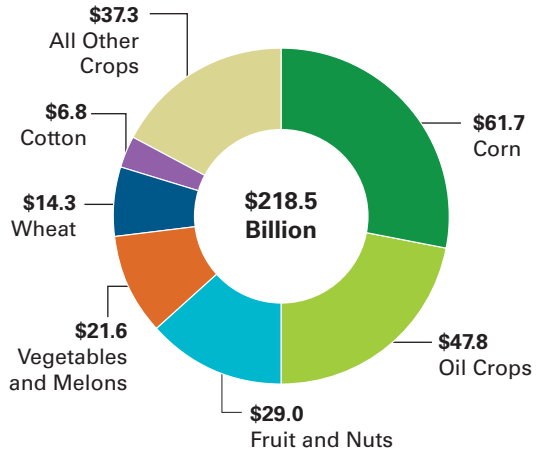
The U.S. is a major wheat-producing country, with output typically exceeded only by China, the European Union and India. **Wheat ranks third among U.S. field crops in both planted acreage and gross farm receipts**, behind corn and soybeans.

The U.S. is the **world's third-largest producer, consumer and exporter of pork** and pork products. U.S. hog operations today tend to be heavily concentrated in the Midwest and in eastern North Carolina.

80 million acres of land are planted to corn, with the majority of the crop grown in the Heartland region. Corn is the most widely produced feed grain in the U.S. and is also processed into a wide range of food and industrial products, such as starch and fuel ethanol.

The U.S. is the **world's leading soybean producer and exporter**. Processed soybeans are the world's largest source of animal protein feed and the second largest source of vegetable oil. Soybeans comprise about 90 percent of U.S. oilseed production, while other oilseeds — including peanuts, sunflower seed, canola and flax — make up the remainder.

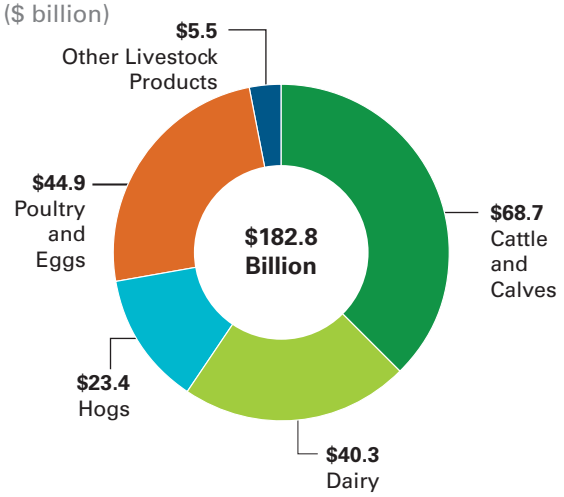
Figure 10: 2013 U.S. Crop Cash Receipts ($ billion)



Data as of December 12, 2014

Source: USDA, Economic Research Service, Farm Income and Wealth Statistics.

Figure 11: 2013 U.S. Livestock Cash Receipts ($ billion)



Data as of December 12, 2014

Source: USDA, Economic Research Service, Farm Income and Wealth Statistics.

U.S. farmers earn more than $400 billion a year in crop and livestock receipts, primarily for corn, soybeans, cattle, poultry, pork and dairy (Figures 10 and 11). This income helps sustain rural economies and communities across the United States and preserves precious farmland for future generations and national food security.

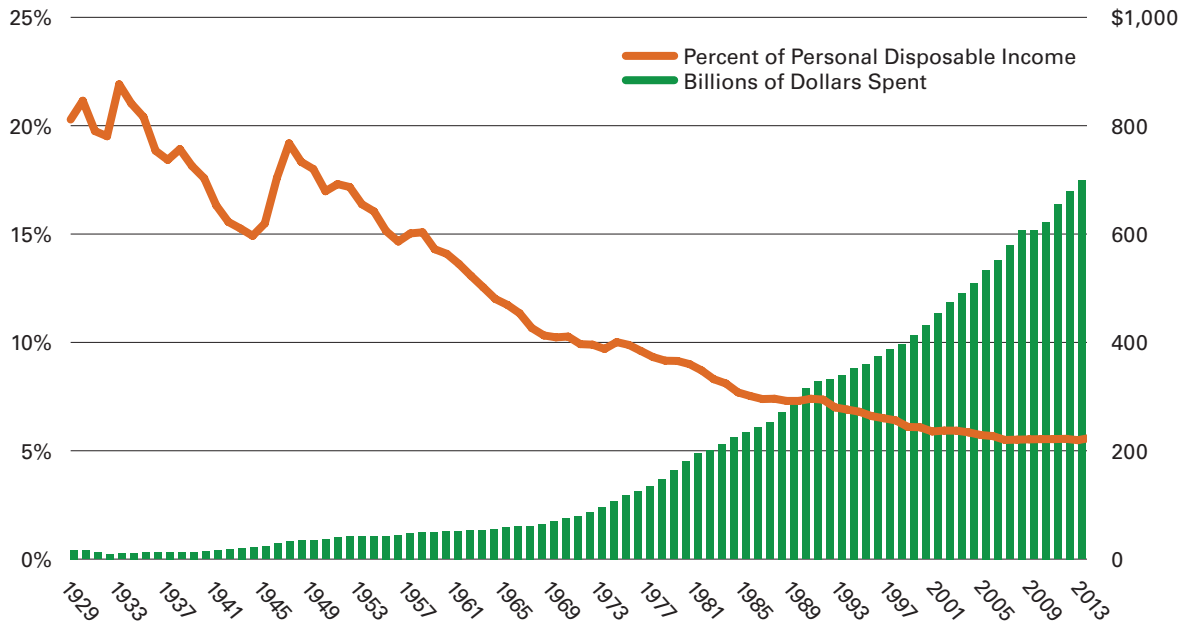
U.S. consumers of farm products have also benefited from this highly productive and powerful agriculture system. Despite occasional price spikes, price increases for agricultural commodities have lagged far behind general inflation for most of the past 30 years. The percentage of disposable income spent on food consumed in the average U.S. household has declined dramatically since the 1920s, from 22 percent down to 6 percent in 2013 (Figure 12). **The average U.S. consumer spends the lowest percentage of household income on food consumed at home among 86 selected major countries**.[36]

U.S. FARMERS: PUNCHING ABOVE THEIR WEIGHT

This enormous agricultural output is delivered by **less than 2 percent of the population** who work directly in production agriculture. Farmers in the U.S. deliver a consistent supply of food, feed, fiber and fuel to the nation at large, and also provide these products to an ever expanding number of foreign countries, supporting a U.S. trade surplus in agricultural products and providing a bulwark against price volatility in global agricultural commodities.

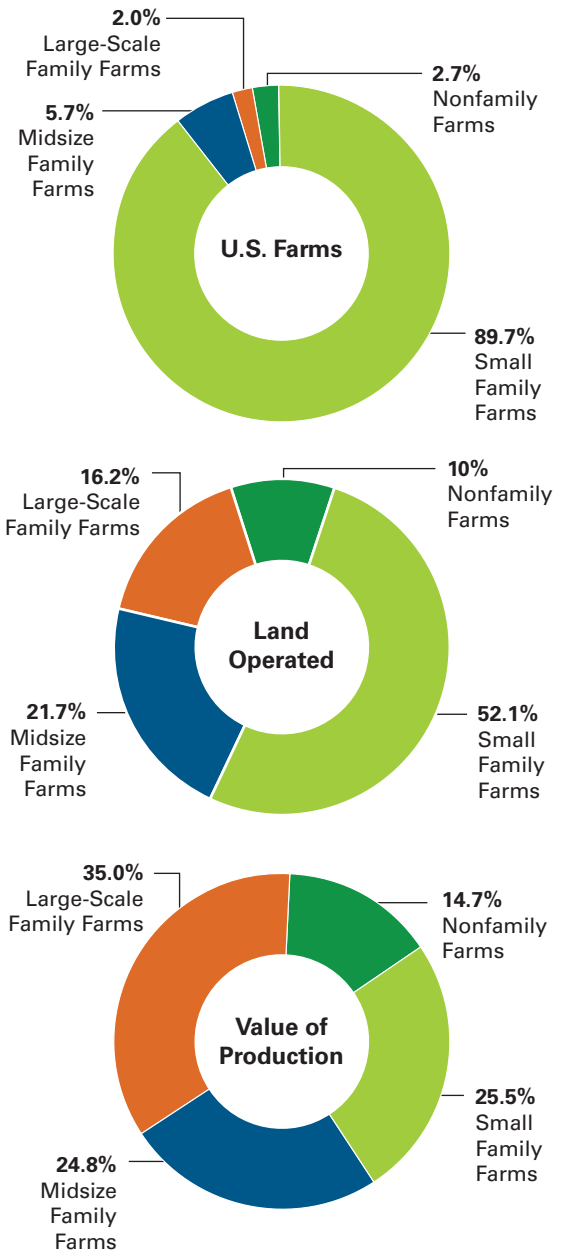
The USDA defines a farm as any place that produced and sold at least $1,000 of agricultural products during a given year.[37]

Figure 12: Percent Disposable Income Spent on Food, U.S. (2013)



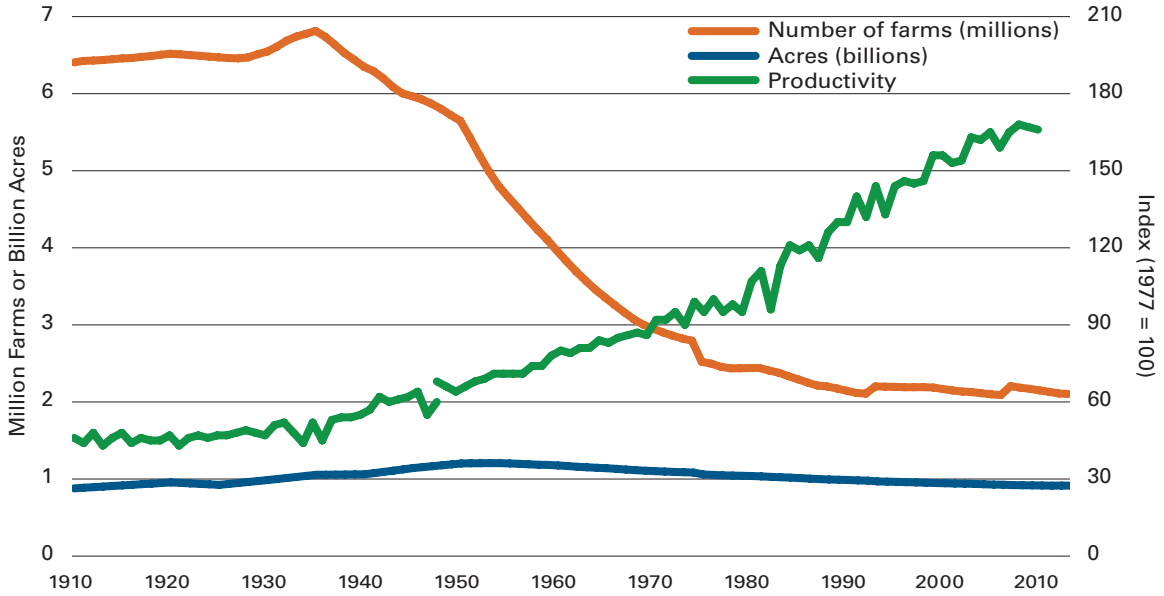
Source: Calculated by the Economic Research Service from various data sets from the U.S. Census Bureau and the Bureau of Labor Statistics, 2013.

Figure 13: U.S. Farm Characteristics, 2011



Source: USDA Economic Research Service.

Figure 14: Number of Farms, Farm Productivity, and Acres Operated in the U.S., 1910–2013



[1] Total factor productivity, or farm output per unit of total factor input (labor, capital, and all other inputs used in production). For more information, see Fuglie et al. (2007).
[2] The break in the productivity line reflects the introduction of new methodology beginning with the 1948 estimate. For more information, see Ahearn et al. (1998, pp. 15-21).

Source: USDA, Economic Research Service, compiled from National Agricultural Statistics Service annual estimates of the number of farms and acres operated (http://quickstats.nass.usda.gov/) and from ERS estimates of farm productivity (http://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us.aspx#28247). Acres operated prior to 1950 are from censuses of agriculture for various yeas, with interpolations between census years. ERS productivity indices prior to 1948 came from Johnson (1990).

More than 97 percent of U.S. farms are family farms in which the majority of the business is owned by the operator and his or her relatives, and fully 90 percent receive less than $350,000 per year in gross cash farm income (GCFI), which is the amount the farm takes in prior to operating expenses. Large-scale family farms — with $1 million or more in GCFI — account for about 2 percent of all farms, but have a disproportionately large share of the value of production (35 percent).[38]

THE U.S. PRODUCTIVITY REVOLUTION

The history of U.S. agriculture development indicates that **TFP growth was the source of its impressive output gains**. Over the past century, U.S. agricultural productivity has increased, the number of farms decreased and the number of acres under production has remained stable (Figure 14).

From 1948 to 2011, USDA data show that total farm output grew by 156 percent, while total inputs (land, labor, fertilizer, machinery, feed and livestock) remained largely unchanged. TFP growth in U.S. agriculture over the period has been steady, at 1.49 percent per year,[39] a rate exceeding that of a majority of other U.S. industries and of most other nations' agricultural sectors.

THE SEEDS OF SUCCESS: INNOVATION AND EXTENSION

Productivity in agriculture has resulted from a **collaborative and sustained commitment** by many sectors of U.S. society — including farmers, the U.S. federal and state governments, entrepreneurs and agribusiness companies, financial institutions, land-grant colleges and universities and extension agents — delivering science-based innovation and best practices to achieve abundant food production with low prices for consumers.

A primary stimulus for TFP growth in the U.S. has been the **collaborative system of public and private agricultural research and development (R&D)** that has boosted innovation in crop and livestock production and in food and beverage processing. While farmers innovate on their farms, experimenting with practices that can boost their productivity, individually they do not have the capacity to conduct longer-term research and development activities. Maintaining high productivity growth requires robust investment in agricultural R&D from both the public and private sectors.

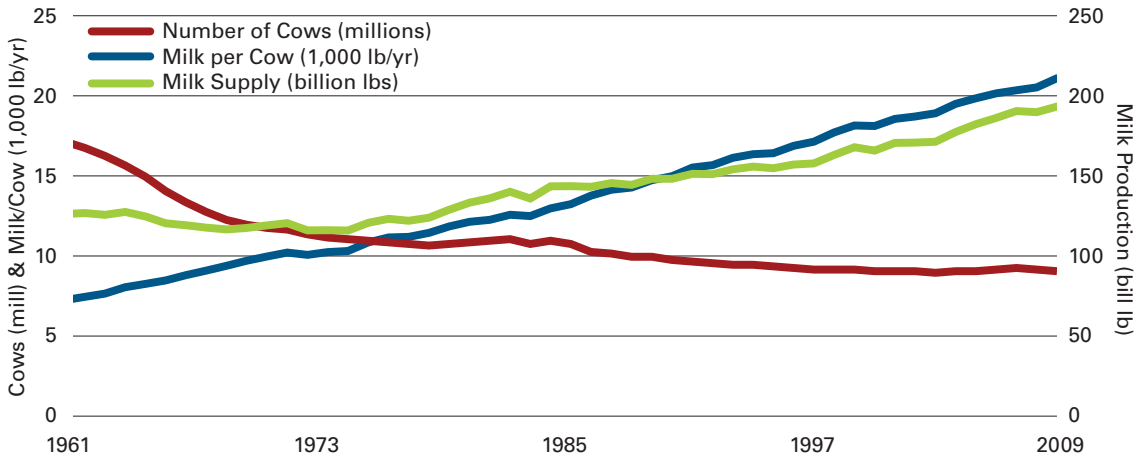
Research for public goods that provide wide benefits to producers and to the larger economy must be maintained by the U.S. government through well-established institutions that are constantly evolving to address new challenges, develop the technologies that will be needed tomorrow and transmit scientific and technical knowledge.

Helping farmers, forest managers and ranchers adopt conservation practices, improve productivity and increase profitability practices is part of a successful TFP growth strategy. To achieve these purposes and build out the larger goals of U.S. food security, nutrition and a well-educated and equipped agricultural sector, the **Morrill Act of 1862** established a system of land-grant colleges and universities, which was augmented in 1890 by the addition of historically black universities and colleges.

A MORE PRODUCTIVE MILK COW

The number of dairy cows in the United States fell by nearly 9 million animals from 1961 to 2009 and has been relatively flat over the past 15 years, reducing the environmental footprint of dairy production per unit of milk produced. At the same time, overall milk output has risen due to the high amount of production per cow (Figure 15). **Genetic improvements from R&D, feed efficiency and better animal care and health practices account for more milk production per cow.**

Figure 15: Trends in Milk Production, Production per Cow and Dairy Herd, U.S., 1961–2009



Source: USDA-NASS, Quickstats & FAO FAOSTAT Databases, May 14, 2013.

Presently more than 100 land-grant institutions across the country conduct agricultural education, research and extension, continually updating the science and technology and sharing critical information and community-based services with farmers, ranchers, the public at large and the global community, supported by federal and state funds as well as private sources.

FRUITFUL INVESTMENTS

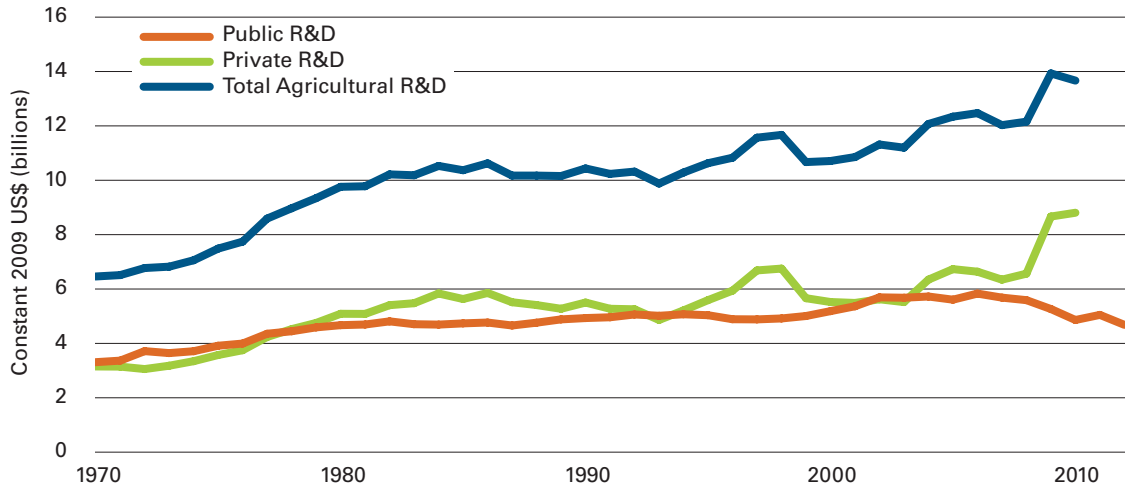
U.S. public agricultural R&D expenditures grew by at least 2.6 percent annually after World War II and continued at a strong pace through the early 1980s. The pace then slackened: **public agricultural R&D growth was flat in the 1980's, and has declined 6 percent since 2000**.[40] (Figure 16)

These recent declines do not bode well for future productivity. R&D investments have a long gestation period and require sufficient and steady investment to bear fruit and to reach agricultural producers after proven practices and technologies become available.

Large contributions from, and investments in, private sector agricultural research and development are also producing dynamic productivity gains and creating synergies with public sector activities. Public R&D typically emphasizes agriculture's relationship with the environment, human nutrition, food safety and issues important for public policy, while private sector investment focuses more on solving needs for marketable goods aimed at specific crops, livestock, machinery and food manufacturing sectors.[41] A large share of private sector research investment now centers on crop seed and biotechnology (Figure 17).

Despite the slowdown in public investment in agricultural R&D, the United States continues to invest more in agricultural R&D than many countries and these investments are assisted by public-private partnerships and by private industry research contributions to academia.

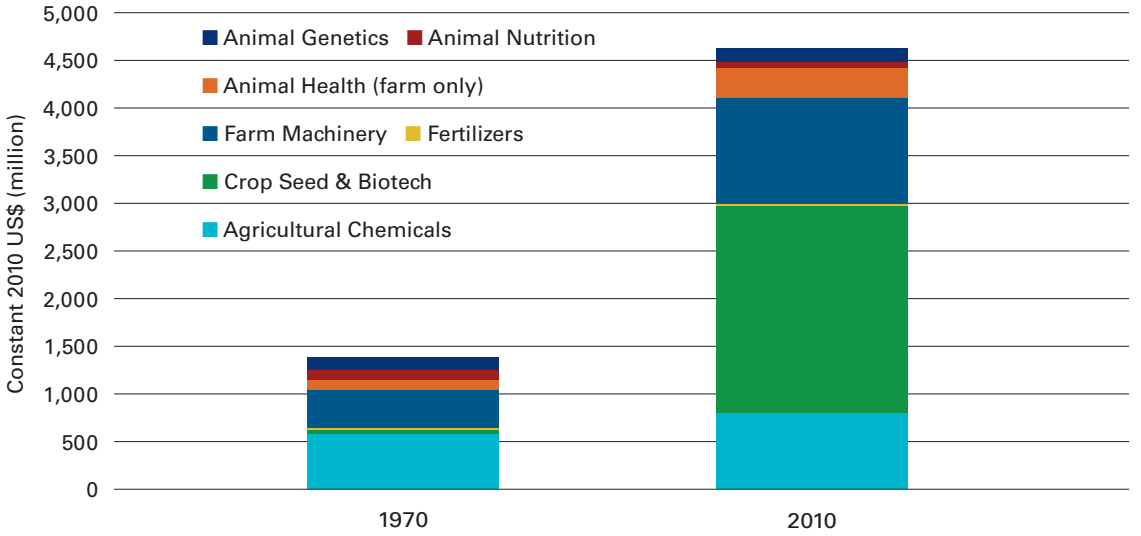
Figure 16: U.S. Agricultural R&D Funding Sources, 1970–2012



Note: Public sector data for 2010–12 are preliminary. Data from 2007–2009 revised from earlier series. Private sector data for 2008–10 are preliminary.

Source: USDA, ERS based on data from National Science Foundation, USDA's Current Research Information System (CRIS), and various private sector data sources. Data are adjusted for inflation by using an index for agricultural research spending developed by ERS. See the documentation for details.

Figure 17: Composition of U.S. Private Sector Agricultural Research, 1970 and 2010



Source: Fuglie, Keith, Paul Heisey, John King, Carl Pray, Kelly Day-Rubenstein, David Schimmelpfennig, Sun Ling Wang and Rupa Karmakar-Deshmukh, 2011. "Research Investments and Market Structure in the Food Processing, Agriculture Input and Biofuel Industries Worldwide." ERR-130, USDA ERS, Washington, DC.

SAVING LAND AND LABOR

In the post-World War II era, new factories opened and higher wages beckoned in and around cities, stimulating the migration of people from rural to urban areas. Less labor was needed on farms as the use of labor-saving technologies picked up, such as tractors, tillers, planters and other equipment for crop production. Capital investments were also made in on-farm storage and livestock rearing facilities and better irrigation equipment.

These types of capital investments have continued up to today, enabling farmers to increase productivity and the size of their operations, creating economies of scale and generating more profits.

For example, in 1970 a farmer could plant 40 acres of row crops and harvest 4,000 bushels per day. By 2005, a farmer could plant 420 acres and harvest 30,000 bushels in a single day.[42] Using mechanization also freed up land previously used for forage for draft animals to devote more land to commercial crop and livestock production.

Irrigation systems help farmers in areas with challenging and variable weather conditions stay productive during drought. Wider use of irrigation and growing adoption of mechanization have allowed the farm sector to increase total output, even as overall land and labor resources used in farming declined.[43] The efficiency of these irrigation systems continues to improve, with farmers now being able to adjust and vary their systems to save water and use it more precisely.

USDA researchers found that between 1982 and 2007, the total amount of land in agricultural use declined by about 5 percent (68 million acres), mainly from decreases in cropland (13 percent decline) and grazed forest land (18 percent decline). Much of this decrease in land used for agriculture was due to enrollment into the **Conservation Reserve Program (CRP)**, the largest federal program providing financial compensation to landowners for voluntarily removing land from production for an extended period of time. Despite the reduction of land used for agricultural production, output of crops and livestock has nearly doubled since the 1950's.

Conservation system in Iowa. Photo Source: Tim McCabe, USDA NRCS

CONSERVATION STEWARDSHIP WORKS

The voluntary **Conservation Reserve Program (CRP)** allows USDA to contract with agricultural producers to conserve environmentally sensitive land. The program offers a yearly rental payment and cost-share assistance in exchange for farmers removing these sensitive lands from agricultural production and managing land to help control soil erosion, improve water quality and protect wildlife habitat. Contract duration is between 10 and 15 years.

"For 30 years, the Conservation Reserve Program has supported farmers and ranchers as they continue to be good stewards of land and water. This initiative has helped farmers and ranchers prevent more than 8 billion tons of soil from eroding, reduce nitrogen and phosphorous runoff relative to cropland by 95 and 85 percent respectively, and even sequester 43 million tons of greenhouse gases annually, equal to taking 8 million cars off the road." USDA Secretary Tom Vilsack, May 29, 2015.

HEALTHY SOILS: THE LEGACY OF THE U.S. CONSERVATION SYSTEM

Agricultural productivity growth in the United States has gone hand in hand with the creation of a dynamic conservation system. As 2015 is the United Nations designated **International Year of Soils**, the U.S. conservation system for soil, water and other natural resources and wildlife provides a model that can be adapted to local needs by other countries to improve soil and water quality and productivity.

The origins of agricultural conservation in America are often connected with the **Dust Bowl** that plagued the Great Plains during the 1930s. Yet the establishment of a conservation system was advocated years before that, particularly by **Hugh Hammond Bennett**, who is considered the father of U.S. soil conservation. Sadly, it took the devastating effects of the Dust Bowl to finally spur a real change in policy.

Today the U.S. conservation system reaches into virtually every rural community with technical and financial assistance that is targeted to local conditions and local needs. It was built by dedicated farmers, scientists and policymakers who were willing to take risks and learn from successive experimentation and long-term practices that are still in use and are being extended across the world.

Enactment of the **Soil Conservation Act of 1935**, at the mid-point of the Dust Bowl era, launched the U.S. conservation system and created the **Soil Conservation Service (SCS)** and major programs to help farmers. In 1937, the **Standard State Soil Conservation Districts Law** was signed, authorizing farmers to organize local soil and water conservation districts. These new districts gave local farmers a voice in federal programs and is widely acknowledged as one of the key reasons for the success of private lands conservation. These districts continue to be the backbone of the United States conservation infrastructure.

By 1938, thanks to new farming practices such as terracing, contouring and cover crop planting, soil stopped blowing away on 65 percent of the affected land. In the fall of 1939, rains would end the drought. By the start of the 1940s, conservation in American agriculture was irrevocably transformed from a commitment by concerned farmers to a **national policy priority** backed by financial resources and political will of the U.S. government.

Today diverse collaborations continue the legacy of the commitment to soil conservation practices. One such example is the **Soil Health Partnership** in which farmers, government advisors, conservation organizations such as **The Nature Conservancy** and private sector companies such as **Monsanto** join together to measure and communicate the economic and environmental benefits of various soil management strategies and provide a set of regionally specific, data-driven recommendations that farmers can use to improve the productivity and sustainability of their farms. The partnership is building a network of demonstration farms that serve as showcases for other farmers to investigate innovative soil management practices, including reduced tillage systems, cover crops and advanced nutrient management. For farmers, healthy soils mean sustained food production for generations to come.

2015
International Year of Soils

Conservation Agriculture ~ According to the United Nations Food and Agriculture Organization (FAO), Conservation Agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. CA is characterized by three linked principles, all of which are practiced widely in the United States and continue to be applied and extended with innovation and greater use of precision data and information systems to farms and livestock production across the country.

1. Continuous no- or minimal soil disturbance (minimum soil disturbance from planting, cultivation, harvest operation or farm traffic, in special cases limited strip tillage);
2. Permanent organic soil cover, especially by crop residues, crops and cover crops; and
3. Diversification of crop species grown in sequence or associations through rotations or, in case of perennial crops, associations of plants, including a balanced mix of legume and non-legume crops.

PRODUCTION PRESSURES AND CONSERVATION COMMITMENTS

During the 1940s, U.S. farmers were called upon to meet the demand for food and agriculture products for a world at war. Wheat production soared to more than 1 billion bushels, almost twice what it had been ten years earlier. Corn production nearly tripled, from 1.1 billion to 2.9 billion bushels.[44]

In 1972, a drought in Russia destroyed 20 percent of its wheat crop, driving up food and grain prices around the world. Buoyed by high prices and with the encouragement to "plant fencerow to fencerow," conservation gains in the U.S. were threatened.

Despite these production pressures, conservation-minded farmers and policymakers had significant victories, particularly in providing farmers the support and incentives they needed to transition to new conservation practices. During the 1950's, a new program, **Soil Bank**, took 29 million acres out of production and diverted them into soil, water, and wildlife protection in exchange for rental payments to farmers for 10 years.

In the 1980s and 1990s, conservation programs focused on mitigating the potentially negative impacts of agriculture on soil, water, air and wildlife. The conservation paradigm shifted from focusing on individual farms to a "landscape approach" targeting large-scale, interconnected landscapes, watersheds and ecosystems. Backed by strong political will from the U.S. government, the **1985 Farm Bill** was the first to contain a specific conservation title. The **1996 Farm Bill** cemented the U.S. government's commitment to conservation **by mandating funding for conservation programs for the first time**.

A NEW CENTURY OF CONSERVATION

The U.S. commitment to conservation took a giant leap into the 21st century with the **2002 Farm Bill**, which increased conservation funding eightfold. Approaches to conservation agriculture increasingly emphasize the importance of partnership, particularly between the public and private sectors. And technology has proven to be as much of a force-multiplier for conservation as it is for any other endeavor. As one example, producers from around the country can receive information and conduct business with conservation agents through a secure online portal that lets individual landowners and land managers track their payments, request assistance, sign documents and request conservation assistance without having to visit an office.

The **2014 Farm Bill** streamlines a number of conservation programs and has ensured linkage between conservation compliance and crop insurance. To be eligible to receive many USDA benefits, including loans, disaster assistance, federal crop insurance premium subsidies and conservation assistance, farmers must comply with requirements for highly erodible lands and wetlands.

The USDA's **Natural Resources Conservation Service (NRCS)** offers voluntary programs to eligible landowners and agricultural producers and provides financial and technical assistance to help manage natural resources in a sustainable manner. Most technical assistance provided by NRCS leads to the voluntary development of a conservation plan that helps achieve a sustainable system that will improve profitability while promoting healthy ecosystems, landscapes and watersheds.

In coming years, Congress will seek to increase private sector involvement in private lands conservation work. In the 2014 Farm Bill, Congress created the **Regional Conservation Partnership Program** to encourage private businesses and organizations to work hand-in-hand with all levels of government to design and implement conservation projects that they feel are important.

USDA National Resource Conservation Service Shares Conservation Knowledge with Afghan Farmers. *Photo source: USDA NRCS*

SHARING THE CONSERVATION SUCCESS STORY

Early leaders in the U.S. conservation service shared their conservation knowledge with other countries, and also learned what other nations were doing that would be applicable in the United States. Today the NRCS provides international program assistance to partner countries through trainings and workshops that exchange scientific and technical information on erosion control, practices for grazing lands and watershed rehabilitation, public policy to enact conservation systems and evaluation of environmental threats in agricultural production areas.

NEW DIRECTIONS FOR FARM POLICY: THE 2014 FARM BILL

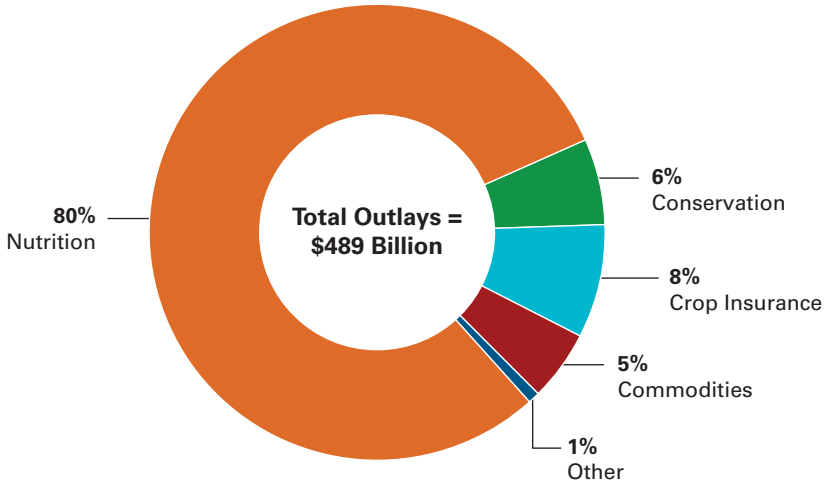
The Farm Bill is major U.S. legislation that authorizes food and agricultural programs for a five-year period, requiring the U.S. Congress to regularly review, update and adjust federal policies and priorities. It has widespread impact and funding consequences, covering production agriculture, nutrition, food safety, rural development, research, trade, crop insurance, international food assistance and conservation.

The current Farm Bill, the **Agricultural Act of 2014**, was signed into law by President Obama in February, 2014. The Congressional Budget Office projected that the legislation would require total expenditures of $956 billion over ten years and would reduce budget deficits by $16.6 billion.[45] Actual expenditures will be different than projected since the underlying economic assumptions are unlikely to hold steady until the legislation expires on September 30, 2018, the last day of fiscal year 2018.

The 2014 Farm Bill restructured the way that farm commodities are supported, expanded crop insurance coverage, supported and consolidated the conservation programs, and revised nutrition assistance through the **SNAP** program (Supplemental Nutrition Assistance Program, formerly known as food stamps). Figures 18 and 19 show the projected outlays under the 2014 Farm Bill for 2014–2018, and the most recent USDA budget outlays since 2005 for all the major sections (titles) of the bill.

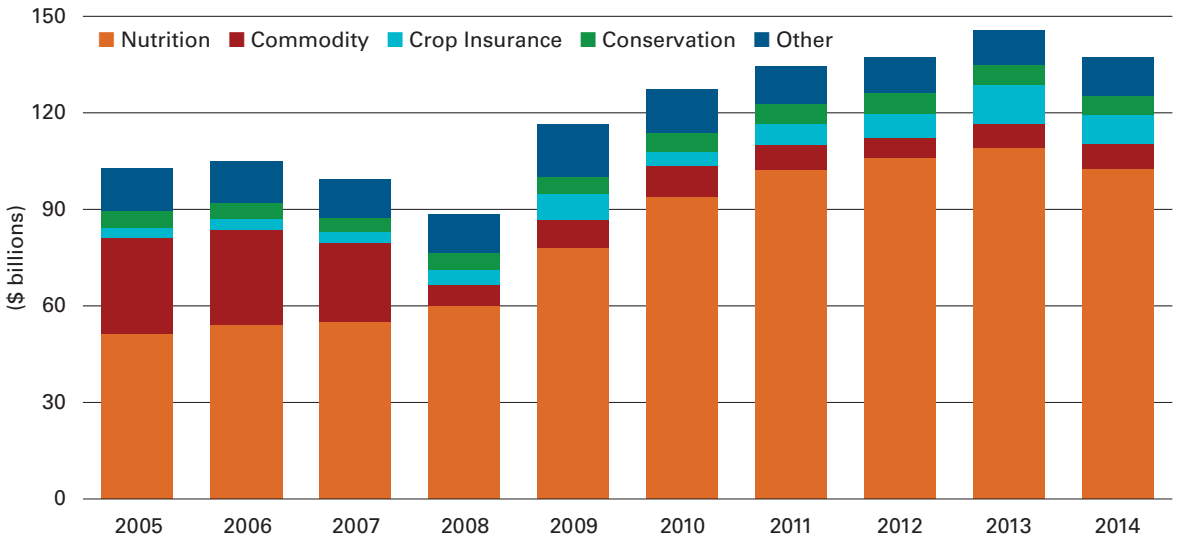
The largest category of expenditure in the USDA budget, 80 percent, is for nutrition assistance (primarily SNAP). This expenditure has increased since 2007, due to the great recession of 2008/2009 in which millions lost employment and housing and required help to meet monthly food needs. Since 2013, the overall number of SNAP participants has begun to decline, along with the expenditures (Figure 19).

Figure 18: Projected Outlays, 2014 Farm Bill, 2014–2018



Source: USDA, Economic Research Service, using data from Congressional Budget Office, Cost Estimates for the Agricultural Act of 2014, Jan 2014.

Figure 19: USDA Budget Outlays, 2008–2014



Source: Office of Budget and Program Analysis, USDA (2014).

FOOD AND NUTRITION SUPPORT FOR HUNGRY AMERICANS

Despite a rich and productive agriculture and food sector, many Americans do not have the means to purchase sufficient nutritious food due to poverty or economic downturns.

With a long tradition of national support for reducing hunger and poverty, the U.S. federal and state governments have partnered with private sector, local communities and charitable and faith-based organizations to provide assistance through a broad array of programs. The social safety net programs include **SNAP** (Supplemental Nutrition Assistance Program, formerly known as food stamps), **WIC** (the Special Supplemental Nutrition Program for Women, Infants & Children, a preventive program providing low-income pregnant women, new mothers, infants and children with nutritious foods and nutrition education), **National School Lunch and Breakfast programs**, and emergency programs such as **TEFAP** (The Emergency Food Assistance Program, which supplement the diets of low-income Americans, including elderly people, by providing them with emergency food).

SNAP, the program created by Congress and President Lyndon Johnson to help hungry Americans **(Food Stamp Act of 1964)**, is designed "to alleviate hunger and malnutrition … by increasing food purchasing power for all eligible households who apply for participation." USDA operates the program, providing monthly benefits to eligible low-income families which can be used to purchase food through use of an electronic benefit transfer system (EBT). The federal government pays 100 percent of SNAP/ Food Stamp program benefits, and federal and state governments share administrative costs (with the federal government contributing nearly 50 percent.)

Recent research shows that SNAP is effective at reducing food insecurity.[46] During the government fiscal year 2014, 46.5 million people received an average monthly per person benefit of $125 to help purchase food, with a total expenditure that year of $70 billion. **Half of all new SNAP participants receive benefits for 10 months or less, and 74 percent of the participants leave the program within two years**. The program also brings benefits to national and local markets, as farmers, manufacturers, and retail grocers all participate in the food value chain for SNAP.

TOWARDS A RISK MANAGEMENT APPROACH

Under the 2014 Farm Bill, support for **commodity production** to farmers for producing corn, wheat, soybeans, cotton, rice, peanuts and other covered crops has shifted away from direct payments to risk management. As a result, there is more reliable support for farmers when they suffer a loss due to a **crop price decline** (price loss coverage payments) or when **crop revenue drops** below an historical level (agricultural risk coverage of a portion of the farmer's losses). Farmers must choose between these two program approaches and enroll to participate. Over time, commodity payments have been reduced as a proportion of budget outlays (Figure 19).

Under this expanded risk management approach, there is greater availability of government-subsidized crop insurance for producers who purchase a policy to protect against losses, with more than 100 crops now insurable. The 2014 Farm Bill increases funding for crop insurance and calls for studies on how to provide future insurance products for swine (pork production), catfish, poultry, specialty crops for food safety losses, biomass sorghum for renewable energy, and for alfalfa production.

SUPPORTING AND STREAMLINING CONSERVATION PROGRAMS

The 2014 Farm Bill continues the long-standing voluntary, incentive-based approach to conservation that is the hallmark of the U.S. system of natural resource conservation and agriculture. Prior farm bills included more than 20 different conservation programs. The 2014 Farm Bill streamlined many of the programs by consolidating smaller programs into the larger programs, and capping the eligible acreage over time placed into conservation reserve using a phase-down approach from 32 million acres in 2014 to 24 million acres by 2018.

A key component of the bill **re-links eligibility for crop insurance with conservation compliance**, ensuring that farmers who wish to receive subsidized insurance must incorporate best practices of conservation on highly erodible land and cannot convert a wetland to crop production. Conservation compliance has existed since the 1985 Farm Bill and is a collaboration success story between farmers and federal and state governments.

As of July, 2015, more than 98 percent of producers have met the 2014 Farm bill requirement to self-certify compliance with conservation measures in order to qualify for crop insurance premium support payments. Compliance is expected to extend conservation provisions for an additional 1.5 million acres of highly erodible lands and 1.1 million acres of wetlands, and reduce soil erosion, enhance water quality, and create wildlife habitat.[47]

THE VITALLY IMPORTANT "OTHER"

With the slimmest portion of the USDA budget outlay pie, the category titled "Other" includes vitally important programs such as agricultural research, development and extension services, rural development activities, forestry, international humanitarian food assistance, energy, horticulture, and providing support for socially disadvantaged farmers and ranchers, military veterans and new farmers.

With less than 1 percent of the annual USDA budget combined, these programs incentivize innovation in renewable energy, encourage young and minority farmers to enter production, provide for the U.S. contribution to global humanitarian food aid and food assistance in developing countries, and help the U.S. maintain its global leadership in research for productivity in food, feed, fiber and fuel.

Crop insurance and good groundwater management can help California orange growers manage production risks from prolonged drought.

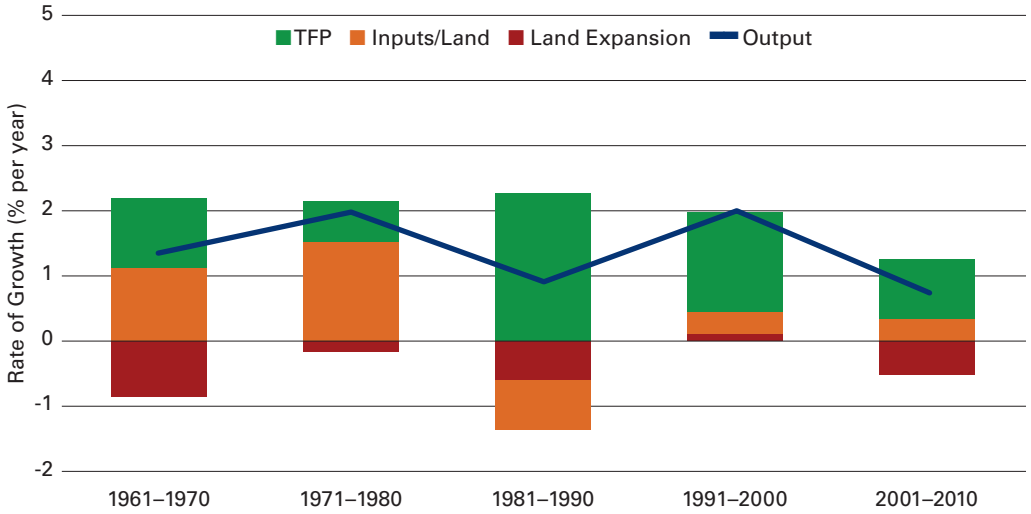
GROWING CHALLENGES FOR PRODUCTIVITY AND THE U.S. AGRICULTURAL VALUE CHAIN

The United States will face new challenges in the coming years in light of increases in consumer demand for agricultural products, global trade and weather volatility due to climate change. Over the past decade, **U.S. agricultural output has slowed** from an historical annual growth rate between 1.5 and 2 percent to less than 1 percent (Figure 20).

The 1970s were a boom decade of agricultural production in the U.S., in which farmers opened up land to produce for export to the former Soviet Union and other countries that needed wheat, rice and corn. But that decade was followed by a farm crisis in which farmers experienced two droughts and mounting debt from overspending in the 1970s. Coupled with the creation of the Conservation Reserve Program (CRP) in the 1980s, less suitable land for production was removed for conservation purposes, leaving the most productive land available for agricultural production and raising the contribution of TFP to overall output.

In the most recent decade, the slowdown in agricultural output growth appears partly due to a slowdown in productivity growth (TFP) and partly due to withdrawal of resources, particularly land, from agricultural production. This trend has been somewhat reversed due to the increase in agricultural prices from 2008 through 2009, when farmers responded to global market signals by producing more crops and livestock and intensifying use of irrigation and crop protection products. Although less land is being converted to agricultural use and conservation compliance is on track, **TFP growth rates have slowed, sparking concern about long-term sustainable agricultural growth**.

Figure 20: Sources of Growth in U.S. Agricultural Output, 1961–2010



Source: Economic Research Service (2015).

Key interlinked challenges and gaps are emerging that will impact the future productivity of agricultural value chains in the U.S., as well as food and nutrition security and the environment:

» **Public funds for agricultural R&D grew from 1948 through the early 1980s, but have increased more slowly and more variably since the 1990s**.[48] Public agricultural R&D is a primary driver of long-term agricultural productivity. If research, education and innovation slow and productivity growth slackens, the inability to keep pace with increasing global demand, climate change, pests and diseases could result in price increases and environmental degradation.

» **Extension and education systems** for communicating new practices, innovations in technology and farm business management are funded jointly by the federal government and state governments, but declines in federal support mean the level of state funding has increased and now accounts for about 80 percent of total extension funding in recent years.[49] This results in **a patchwork of extension capacity** across the nation, with the number of full-time extension staff dropping after 2007 due to decline in state budgets from the recession. Public extension across all parts of the nation is vital for ensuring that farmers and ranchers from coast to coast are able to keep pace with technology and innovation and increase their opportunities for success.

» The number of farm operators over age 55 is now 68 percent, with those under 35 at only 5 percent,[50] creating a growing **"farmer gap."** It is crucial for new farmers to step in and fill the roles vacated by retiring farmers, but young people in rural areas are finding it increasingly difficult due to higher land costs and high capital requirements to launch farming businesses.

» **The U.S. transportation infrastructure — roads, railways, inland waterways, including locks and dams and ports — has a significant impact on productivity in agriculture** by making new technology more accessible to farmers and delivery

of farm commodities to markets less costly and more timely. Rural broadband is also critical for rural producers to be able to access data, services and enable intelligent precision agriculture operations. But an **"infrastructure and broadband gap"** exists due to lack of public sector investment over the past decade.

» **Hunger and nutrition challenges persist in the United States** despite an abundance of food. Comprehensive solutions to reduce poverty and to ensure access to food, while reducing loss and waste of food in the agricultural value chain, will be paramount.

» **Climate change and weather volatility** will result in more drought, flooding and water and soil quality issues in the coming decades. **Policymakers must create an enabling environment to foster adoption of new technologies and practices** that improve yield and increase water use efficiency and water quality and that can support precision production systems to reduce the environmental impact of agriculture and help mitigate its contributions to climate change.

» **Many consumers in the United States experience a "trust gap" when it comes to food production.** Most consumers are several generations removed from farming and rural life and are not familiar with agricultural production methods. Yet there is a growing interest among consumers regarding the origins and makeup of the food they eat. With increasing access to modern information technology, many consumers believe that it should be possible to easily find out what is in their food and where it came from. Forging new relationships among consumers, farmers and other participants along the agricultural value chain — and ensuring that clear, science-based information is widely available — are critical to realizing the promise of modern agriculture. **Farmers, agribusinesses, consumers and the government must seize opportunities for dialogue and forge new relationships to bridge this gap**.

THE U.S. AGRICULTURE & FOOD VALUE CHAIN

An agricultural value chain (AVC) is the sequence of steps and relationships among the many actors from farm production through delivery of an agricultural product to the consumer. The U.S. AVC is diverse and complex, with multiple avenues for producing and delivering food, feed, fiber and biofuels. To keep pace with changing consumer preferences, increasingly volatile weather patterns and expanding global markets, U.S. AVCs must be innovative, agile and adaptive, which can take place only in a supportive regulatory environment.

GHI's five strategic policy goals introduced on page 14 create the enabling environment for AVCs to increase productivity, reduce post-harvest loss and waste, protect the environment and natural resources, and meet consumers' needs and demands, both domestically and globally.

FIVE STRATEGIC POLICY GOALS

Farmers/Producers

U.S. farmers are relatively few in number, yet despite the inherent risks in farming, they are highly productive and responsive to market forces. Maintaining productivity and meeting consumer demands require careful planning and innovative thinking, as well as access to information, good quality inputs, financing and risk management tools to protect against price fluctuations. Consistent availability of skilled and seasonal labor helps ensure a sufficient supply and reasonable prices of food. Most important are transparent and consistent regulations for land and water use and a sound financial system that provides operating and capital loans on fair terms. Research and development of new technologies, such as improved crop genetics, advances in livestock nutrition and better ways to control disease and pests, allows farming to keep pace with increased demand and helps build resilience in the face of volatile weather, new pathogens and a changing environment. Equally important is assuring that farmers and ranchers learn about and are able to afford these technologies, so they can select and apply the right ones for their production needs. They benefit from training and education from land-grant colleges and universities, as well as advisory services from private sector input suppliers, including new information and data technologies to support precision agriculture practices.

Agricultural Service Providers

Service providers, whether from the private sector or from government and academic extension agencies, help farmers adopt better practices and new technologies, and improve business and farm management skills. Support from USDA for conservation agriculture methods and livestock production can help farmers reduce the environmental impact of agriculture and farming. Private sector agronomy and livestock experts provide farmers with products that are tailored for local agro-ecological conditions. Programs that certify professional qualifications, such as the Certified Crop Adviser (CCA) program of the American Society of Agronomy, enhance industry standards and ensure farmers receive information and training in best practices of stewardship, sustainability and productivity. Agricultural service providers are creating easy-to-use software and data applications for managing information to help producers analyze their crop, livestock and forestry operations, predict weather conditions and optimize production by reducing water and other resource use.

Aggregators/Traders

Cooperatives and aggregators help move agricultural products from the farm into specialized warehouses for storage or transport it to processing sites. Farmer cooperatives aggregate and market agricultural goods on behalf of their members and also help them access seeds, fertilizers and services at lower prices. Aggregators and traders need smooth functioning markets, technology such as cold chain systems and transportation infrastructure such as roads, waterways, rail and ports, to move goods and contain costs. They play an important role in the value chain by removing market risk from primary producers, efficiently moving agricultural goods to processors and retailers, and preventing loss and waste of perishable products — which, in turn, reduces consumer costs. They benefit from transparent price discovery and risk management mechanisms, such as futures markets, technologies that transmit real-time information about infrastructure bottlenecks, regular reports on production progress and expectations throughout the growing season, and precision information and data technologies that trace products from the farm through to processors.

Financial Services and Risk Management

Access to credit on fair market terms through government-supported programs or from the private sector, such as banks and equipment suppliers, enables farmers to obtain seeds, fertilizer, livestock and land and to invest in capital improvements, including machinery and storage facilities to enhance productivity and reduce post-harvest loss. Government-supported programs, such as crop yield and revenue insurance, as well as private insurance, commodity futures markets and other contracting mechanisms, give farmers protection in case weather or other conditions result in reduced yields or adverse prices.

Agro-Processors and Manufacturers

Agro-processors add value to raw agricultural products, generate employment in both rural and urban areas, and provide opportunities for nutrient fortification. They process agricultural products and add different ingredients together to create a wide variety of foods, which are then packaged to preserve quality and freshness and to supply portion sizes that are practical for consumer use. Processors need access to financing and equipment for safe and efficient food processing, skilled labor to operate processing, manufacturing and packaging centers. Important for both food safety and consumer knowledge are practical systems to track the sources of food products and their ingredients. Agro-processors also need predictable and consistent tax, tariff, trade, manufacturing and food safety policies so they can supply safe and nutritious products to retailers and consumers.

Retailers

The U.S. retail market is highly diversified and competitive, with food products sold at both large and small grocery stores, discount supermarkets, convenience stores and pharmacies. There are specialized food stores and restaurants ranging from fast-food to fine dining. Loyalty cards, emailing feedback questionnaires, talking to consumers as they shop, and closely monitoring sales data are among the many ways retailers identify foods and services their customers want. With the variety of incomes and consumer preferences found in the United States, as well as changing demographics, retailers need new and improved methods to help them keep up-to-date with trends in their target markets and make adjustments in their inventory and marketing strategies. New services are constantly made available, such as using on-line transactions for same-day delivery of groceries to consumers. Adjusting to consumer demands drives retailers to seek changes throughout the supply chain. One example is requiring more traceability, which largely relies on e-based systems to track products back to the farm level. Donating product that is close to its end-date to food banks and congregate meal centers, recycling food waste into energy products, and better inventory control are among the many ways that U.S. retailers are reducing food waste.

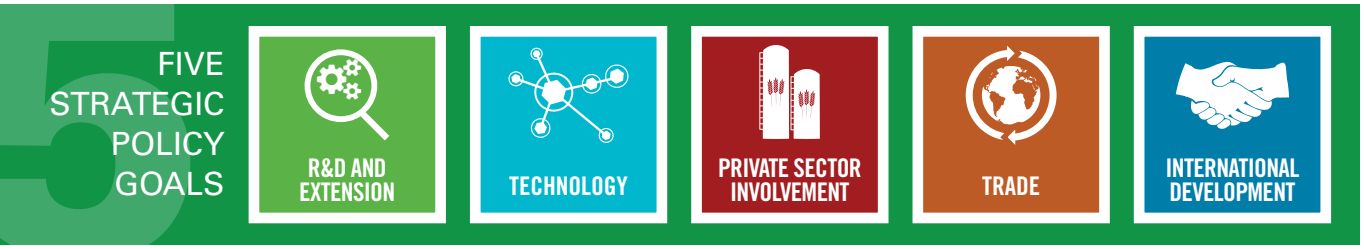
Consumers

Meeting diverse and growing consumer demand is driving dramatic changes in the U.S. AVC, where some consumers want to buy in bulk, while others want fresh and prepared foods in single-portion containers, and many more are reading labels and asking about ingredients and production methods. USDA and other government institutions can provide consumers with science-based information about diverse agricultural production methods and their respective benefits and tradeoffs. Consumer research indicates that the top three concerns for consumers when it comes to purchasing food are expiration date, the nutrition facts panel and the list of ingredients.[51] Food safety issues are also paramount for consumers; USDA's inspection and quality control offices and the Food and Drug Administration (FDA) play vital roles in keeping the food supply safe. Information technology, such as new food education apps, allow consumer to learn more about their food right in the grocery store. Information on nutrition and healthy food choices can be found on the USDA website, ChooseMyPlate.gov, and information on food science and food safety can be found on the FDA website. Consumers have a vital role to play in reducing food waste in the home and in retail settings. They also drive changes in the AVC towards fair labor standards for production of agriculture and food products and other social and environmental issues.

GROWING SOLUTIONS THROUGH VALUE CHAIN INNOVATION AND COLLABORATION

The abundant and productive U.S. agriculture and food system benefits from long-term investments in research, education, technology and innovation. Exciting new developments in agricultural science, collaborations between public and private sectors, and the application of technology can help provide the food, feed, fiber and fuel needed by the U.S. and global markets in a more sustainable way. The U.S. can harness its powerful legacy of experience in conservation, agricultural research, knowledge and extension and promote public policy and collaboration to meet consumer and environmental needs.

This section of the GAP Report® presents case studies and innovations that demonstrate how value chains in the U.S. are becoming productive and sustainable by conserving natural resources, adapting to and helping mitigate climate change, and improving nutrition and livelihoods. **GHI's five strategic policy goals** (described on pages 14–15) build an enabling environment, encouraging investments along the value chain. Accompanying each case study in this section of the report are icons symbolizing which policy goals contribute to its success.



COLLABORATIONS TO CONSERVE SOIL, WATER, AND PRODUCE MORE SUSTAINABLY

Encouraging and supporting farmers to expand adoption of soil conservation practices that prevent sediment and nutrient loss, along with enhancing water availability, improves productivity while reducing environmental impact. Research priorities target the enhancement of crops to protect them against drought and to ensure consistent supplies and prices. Partnerships are forming between government, farmers, private sector and conservation organizations to conserve valuable water resources and improve water quality.

INDIANA LEADS A COLLABORATIVE CONSERVATION MOVEMENT

Indiana is the only state in the country to adopt a model among many partners that measures and tracks conservation impact on a statewide scale. The **Indiana Conservation Partnership (ICP)** is comprised of eight Indiana agencies and organizations with a common mission to provide technical, financial and educational assistance to implement economically and environmentally compatible land and water stewardship decisions, practices and technologies.

The collaboration started with joint leadership between the **Indiana Division of Soil Conservation (IDSC)**, the **U.S. National Resource Conservation Service (NRCS)**, and the **Indiana Association of Soil and Water Conservation Districts**. ICP has achieved significant farmer participation in conservation practices, with measurable improvements in soil and nutrient conservation and in water quality.

Indiana is the only state using Region 5 EPA algorithms to measure and map progress of authenticated practices, such as swales (depressed sections of a field designed to reduce runoff and increase infiltration of nutrients and water into the soil), grass filter strips that buffer waterways from soil and nutrient runoff, and cover crop planting. (See Conservation Practices sidebar.)

Indiana has finished the first tillage transect — a cropland survey including information on tillage methods, plant cover, and residue by county. Through education and encouragement, **Indiana farmers planted over 1 million acres of living plant cover in 2014**.[52]

The use of cover crops, in addition to other conservation methods, such as reduced-tillage, nutrient management, precision farming and buffer zones, has made Indiana a national leader in collaboration to achieve soil conservation and water quality. Going forward, Indiana will continue to monitor results for prevention of sediment erosion and nutrient reduction and expand this collaborative partnership across the state.

To view ICP Nutrient Load Reduction Maps, visit http://icp.iaswcd.org.

Buffer strips are sections of grass or cover plants that surround a field and reduce nutrient runoff and prevent soil erosion. Photo source: USDA Natural Resources Conservation Service.

CONSERVATION PRACTICES IMPROVE SOIL QUALITY AND PRODUCTIVITY

Conservation practices, including the use of cover cropping, have been used widely across the globe and by farmers throughout history. U.S. Presidents Thomas Jefferson and George Washington were advocates of cover crops and other agricultural conservation techniques, and incorporated cover crops on their own farms.[53]

There are many different plants (including ryegrass, hairy vetch, and various species of clover) that can be used as a cover crop; each crop provides different benefits, allowing the farmer to meet a specific soil need. While some cover crops are harvested for profit, the primary use of cover crops is to increase the sustainability, yield and efficiency of farm production and improve soil for the main crops of corn, wheat, soybeans or other row crops that are planted after the cover crops mature.

Benefits of cover crops include providing ground cover that reduces soil erosion from wind and rain and increasing the infiltration of excess surface water to reduce runoff and to conserve soil moisture. Below the surface, the root systems of the cover crops support essential soil structure, absorbing and cycling nutrients [particularly nitrates (N), phosphates (P), and potassium (K)] and reducing soil compaction. The organic matter left behind by cover crops directly contributes to the levels of Soil Organic Matter (SOM), which has a significant impact on soil fertility, yield and production efficiency. This has both economic and environmental impacts; input use and costs are lowered and contaminated water runoff is reduced.

Other common conservation practices include no-tillage (or reduced tillage) systems, buffer strips, grass waterways and nutrient management.

COLLABORATIVE RESEARCH FOR DROUGHT TOLERANCE AND WATER USE EFFICIENCY IN MAIZE

Maize (corn) is one of the world's most important grain crops, contributing to food security through direct human consumption as well as used in animal feed, fuels, and a wide array of industrial purposes.

Despite productivity gains over the past 80 years in the U.S. Corn Belt region and having one of the smallest water footprints of any grain crop, maize remains vulnerable to drought conditions, especially at the flowering and grain fill periods of plant development. Achieving breeding and management improvements in maize for different intensities, durations and timings of drought is a challenge to the research community, and requires strong collaboration between plant breeders, researchers, private sector companies and farmers who will have the option of using the eventual maize seed products in specific agro-ecological conditions on their farms.

Private sector companies are collaborating with farmers in thousands of field trials to test new breeds of drought tolerant maize and to ensure higher yield, during both drought and normal conditions, as farmers do not want a yield penalty in years when drought is not an issue. **DuPont Pioneer** has collaborated with more than 1,000 farmers to conduct on-farm side-by-side trials to obtain 10,731 comparisons in the U.S., testing drought-tolerant maize hybrids (AQUAmax®) against regular hybrids.

In those trials, farmers chose the hybrids they wanted for a "best-practice" comparison with the new AQUAmax® hybrids. The researchers found that the drought-tolerant products provided 6.5 percent higher yield under drought conditions, as well as 1.9 percent higher yield under favorable growing conditions — a "win-win" for farmers.[54]

To guide high level research priorities, the **Drought Research Council**, a team of experts in plant breeding, physiology and agronomy from universities and DuPont Pioneer, meet at regular intervals, sharing ideas and expertise. Together, they are developing a better understanding of farmers' current and future needs and planning research into genetics and agronomy of crop drought tolerance.

The Drought Research Council calls for priorities in research that can make a significant difference in addressing future global water challenges for crops.

Under-studied but vital priorities include gaining a better understanding of the growth and development of plant root systems for water and nutrient uptake and a focus on the plant reproductive stage of development, since this is the stage where plants are most vulnerable to heat and drought stress.[55] Research must also emphasize strong collaboration with farmers via multi-location field trials in a range of agro-ecological conditions so that results can be delivered with farmer need and growing conditions at the heart of the effort.

FIBER PRODUCTIVITY: THE CASE FOR COTTON

Cotton is one of the most important textile fibers in the world, accounting for 35 percent of total world fiber use. The lint provides fiber for clothing, towels, sheets and other home goods. The cottonseeds from the plant are crushed, with the oil being used as a cooking and salad oil and the hulls and meal going to feed livestock feed.

The U.S. ranks third in production behind China and India and is a leader in exports, accounting for over one-third of global trade in raw cotton.[56] The U.S. cotton industry accounts for more than $25 billion in products and services annually, generating about 200,000 jobs in the industry sectors from farm to textile mill.[57]

Dramatic increases in U.S. cotton productivity have occurred since the 1980s (Figure 21). While cotton yield has increased by 55 percent overall during this time, acres of land used per pound of cotton produced declined by 30 percent; total tons of soil erosion per pound of cotton produced declined by 68 percent; irrigation water per pound of cotton produced declined by 75 percent; energy use per pound of cotton produced declined by 31 percent; and greenhouse gas emissions (GHG) per pound of cotton produced declined by 22 percent.[58]

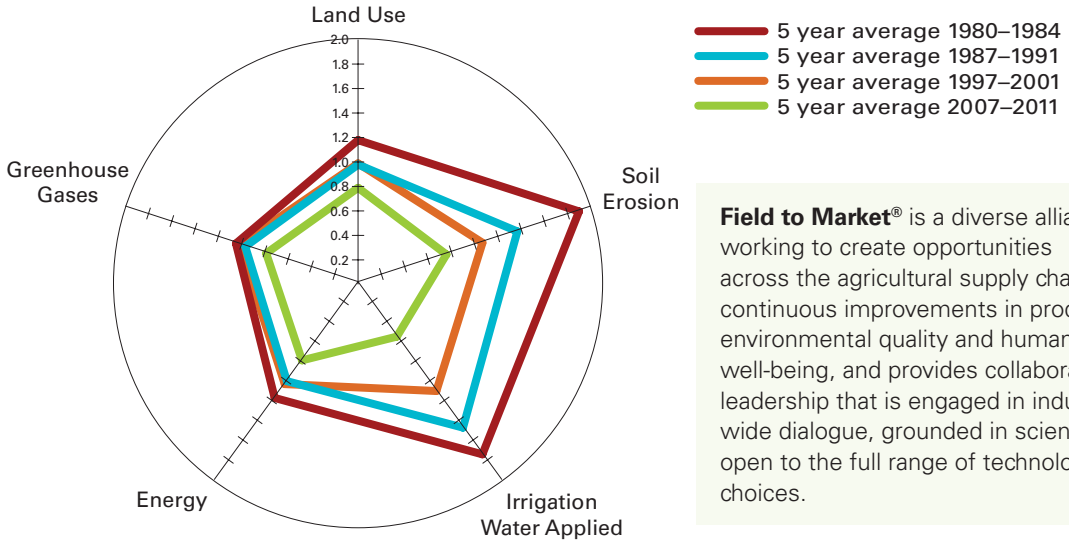
What accounts for this dramatic increase in cotton productivity?

Advances in genetically improved seed varieties, and more **precise machinery and production practices such as conservation or reduced tillage, precision irrigation, crop rotations and pest management systems**, all helped cotton farmers produce more with less environmental impact.

Farmers used to face pressure from pests like bollworms that eat the cotton plant, which not long ago reduced yields in the U.S. by an average of 4 percent and by 29 percent in some states, such as Alabama.[59] With the advent of biotechnology for cotton, productivity has increased and accelerated since 1996, particularly due to the adoption of Bt cotton (in which cotton plants produce a protein from the bacterium *Bacillus thuringiensis* that kills the bollworm) and HT (herbicide tolerant cotton, developed to survive application of specific herbicides that previously would have destroyed the crop along with the targeted weeds). Seed companies such as **Monsanto** produce both Bt and HT cotton seeds, as well as cotton that has both traits combined ("stacked"). By 2015, 94 percent of cotton acres planted in the U.S. use either Bt, HT or the combined "stacked" variety of cotton.[60]

Cotton farmers also benefit from extensive collaborative partnerships between more than 15 universities, 14,000 growers and companies such as Monsanto in order to address the challenges from aggressive and herbicide-resistant weeds. Training sessions on how to implement effective and sustainable weed management systems help farmers reduce the destructive weed impact on cotton growth. Monsanto cotton seeds (Bollgard II® XtendFlex™) that are tolerant to three different herbicides are providing farmers with powerful options to grow more with less environmental impact.

Figure 21: Index of Per Pound Resource Impacts to Produce Cotton Lint, U.S., 1980–2011



Field to Market® is a diverse alliance working to create opportunities across the agricultural supply chain for continuous improvements in productivity, environmental quality and human well-being, and provides collaborative leadership that is engaged in industry-wide dialogue, grounded in science and open to the full range of technology choices.

Source: Field to Market, 2012 Environmental and Socioeconomic Indicators Report, Cotton.

WATER USE EFFICIENCY, QUALITY AND MANAGEMENT

Water is arguably the most prized natural resource for agriculture and consumers alike. Water availability for agriculture is impacted by climate change, extreme weather variability and inefficient use and management. Most drinking water in the middle United States comes from surface waters, of which 80 percent drains through agricultural lands. Consumers are worried about possible health implications and environmental impact, while farmers worry about nutrient loss and profitability.

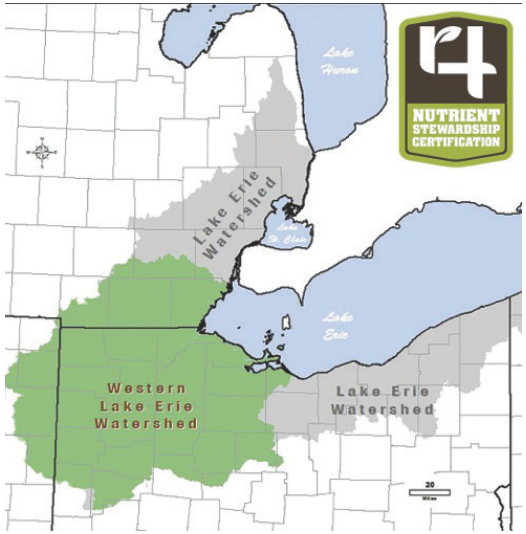
Many collaborative approaches are now being harnessed to improve the availability and efficiency of water use and water quality. Multi-institutional coordination across federal, state and local levels, along with farmer and producer participation, will be required to conserve water and improve its quality so that farmers and consumers have resources for the future. The following case stories emphasize collaboration to design solutions, working along the entire value chain from farmer to urban consumer.

4R CERTIFICATION IMPROVES WATER QUALITY

While farmers need phosphorous fertilizer to help improve crop yield, application in the right amount, at the right time and in the right locations on the field is essential to reduce runoff of the nutrients. In recent years, algal blooms on Western Lake Erie have increased, growing large enough in some areas to be seen from outer space. Phosphorus runoff from surrounding agricultural lands contributes to the problem — and groups, from government and businesses to farmers and NGOs, are joining together and taking action.

To help keep phosphorous on farmland and reduce loss to water, **The Mosaic Company** and **The Mosaic Company Foundation** are partnered with **The Nature Conservancy (TNC)** in support of a multi-sector initiative to pilot the 4R Nutrient Stewardship Certification program. The program is governed and guided by the 11-member **Nutrient Stewardship Council**, a diverse set of stakeholders from business, government, university and non-governmental sectors with a common goal of maintaining agricultural productivity while also improving the long-term quality of Lake Erie and its contributing watersheds. The **Western Lake Erie Basin (WLEB)** spans 7.2 million acres across Indiana, Michigan and Ohio and provides drinking water to 11 million people and habitat to more than 50 percent of Great Lakes fish species.

The 4R Nutrient Stewardship Certification Program encourages agricultural retailers, service providers and other professionals in the Western Lake Erie Basin to adopt proven nutrient application best practices of the 4R concept: ***Right Nutrient Source*** (matching the fertilizer type to the needs of the particular crop) at the ***Right Rate*** (optimizing the right amount for the particular crop) and ***Right Time*** (applying fertilizer when it can be optimally used and avoiding application on frozen



Farmers and TNC staff meet in NW Ohio during the Western Lake Erie Basin Pilot Audit. Photo source: © Randall L. Schieber

ground or when a large rainfall is forecast) in the ***Right Place*** (apply precisely where the fertilizer is needed). Adoption of these best practices helps farmers achieve sustainable plant nutrition management while also considering water quality. The approach also provides a science-based framework for sustained crop production, while considering specific individual farms' needs.

To date, 4R-certified nutrient service providers deliver service to 1,580 farmers on 630,000 acres in the Western Lake Erie Basin. In addition, 50 nutrient service providers have begun the 4R certification process. The Ohio AgriBusiness Association estimates that the program will hit the million acre mark in WLEB-4R certifications by late 2015.

Studies show that between 2009 and 2014, the new steps farmers are taking with collaborative assistance of the USDA National Resources Conservation Service have reduced annual nutrient and sediment losses by approximately 7 million pounds of nitrogen, 1.2 million pounds of phosphorus, and 488,000 tons of sediment in the Lake Erie Basin.[61]

IOWA ALLIANCES IMPROVE FARMER PROFITABILITY, PRODUCTIVITY, AND WATER QUALITY FOR CONSUMERS

While drinking water in the U. S. is among the safest in the world, elevated levels of nitrate, coupled with increasingly strong weather events and a persistent low oxygen "dead zone" in the Northern Gulf of Mexico, has the attention of businesses, governments and non-government organizations.

Farmers in Iowa and across the nation are making tremendous strides in reducing soil erosion and improving water quality with regard to sediment and phosphorus. However, many challenges remain for reducing nitrate loss, particularly in agricultural areas with significant sub-surface drainage or tiling (underground pipes in fields that remove excess water).

In Iowa, the situation has city municipalities and rural interests working toward a mutually beneficial goal. Even though U.S. corn farmers increased their nitrogen use efficiency by 105 percent between 1980 and 2014, nitrate levels in Iowa's waterways and in other Midwest states increased due to land use changes and seasonal climatic variability.[62] That's why diverse stakeholders worked together to develop an **Iowa Nutrient Reduction Strategy** in 2013 that set a goal to reduce nutrient loading in water by 45 percent. This will benefit waterways in Iowa and those downstream.

To help achieve the Nutrient Reduction Strategy, three leading agriculture associations formed the **Iowa Agriculture Water Alliance (IAWA)**[63] to bring new ideas and resources together along with local expertise. IAWA is building private-public partnerships to increase the adoption of conservation practices that will lead to improved profitability for farmers and safer drinking water for consumers.

IAWA focuses on increasing the pace and scale of farmer-led efforts that improve water quality as well as designing solutions that maintain or increase productivity. Helping farmers reframe efforts around improving profitability and total return on investment, and not only on producing more agricultural output, is part of the goal. It is not uncommon for a small portion of crop fields to produce low yields despite high inputs. Using precision analytics can improve return on investment by replacing row crop production on these acres with conservation practices that yield other benefits including improved water quality and biodiversity.

Improving profitability and environmental outcomes also means that public conservation services and private business planning tools and services need to work together in new ways that improve farmers' competitiveness. IAWA is working with multiple partners to integrate conservation planning into private sector precision agriculture, record keeping and decision support platforms. In addition, IAWA is developing programs that encourage agriculture retailers to more deeply engage their Certified Crop Advisors to directly enroll farmers in conservation practices and conservation planning.

Farmers are showing interest in newer, innovative edge-of-field practices like **bioreactors** and **saturated buffers**. Bioreactors work by diverting tile drainage flow through a bed of wood chips where microorganisms work to convert nitrate in the water to harmless nitrogen gas while reducing up to 43 percent of nitrate content in water before it reaches the stream. Saturated buffers catch water from tile lines, slow the flow and filter water through vegetation, thereby reducing nitrate concentrations in water by up to 91 percent before it reaches the stream.

Iowa will soon have the nations' largest installment of bioreactors and saturated buffers thanks to work pioneered by the **Iowa Soybean Association** and led by farmers in a small watershed in Northern Iowa. Other public and private partners have also now joined the effort.

Edge of field practices help improve Iowa water quality. Photo source: Joe Murphy/Iowa Soybean Association

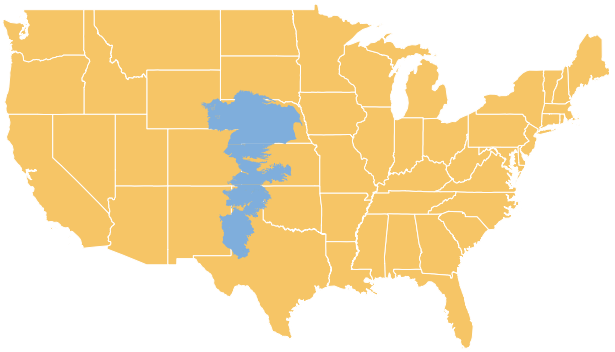
Together, cities and rural interests must forge new relationships and programs. IAWA and multiple municipalities are in the early stages of designing a framework whereby waste water treatment facilities can use offset nutrient loading reductions as a result of investing in farmers' conservation practices. This will help cities meet more stringent future permit obligations in a more cost-effective manner than if they were to only make investments in their nutrient removal operations. This strategy will help to provide clean water and increased flood protection in a way that's cheaper for rate payers.

NEBRASKA: A GLOBAL LEADER IN GROUNDWATER MANAGEMENT

Investments in irrigation infrastructure have played an important role in increasing U.S. agricultural productivity. Attention to good governance of natural resources has also been important, especially in agricultural systems that depend heavily on irrigation, such as those that are typical in the state of Nebraska, which has more irrigated area than any other state in the U.S., including California, and more than all but a dozen of the world's countries.

Most of Nebraska's groundwater comes from the vast **High Plains Aquifer System**, which includes the Ogallala aquifer, one of the world's largest, and covers several states from Nebraska though Texas. This system stores 1,975 million acre-feet (almost 2,500 cubic kilometers) of groundwater in Nebraska alone. However, its southern portions have seen significant drops in the water table since intensive irrigation began more than 70 years ago. Less well known is the fact that over the entire period, Nebraska has lost on average less than 0.5 percent of its historic water levels, even in the face of significant increases in total area irrigated.

Plentiful recharge of the aquifer in the sandy soils of Nebraska's Sandhills region contributed to this positive outcome, as did Nebraska's decision in 1972 to establish a unique system of **Natural Resources Districts (NRDs)**. The state's 23 NRDs, organized around river basin boundaries, are overseen by locally elected governing boards with taxing powers and authority to manage a wide range of natural resources, including ground water. Established prior to the significant expansion of irrigation in the state, they have the major responsibility of governing the vast groundwater resources that are so vital to Nebraska's economy.



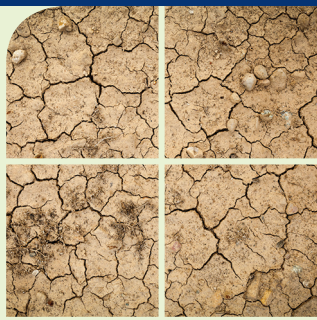
Staff at the NRDs work with their boards and the state to develop locally-tailored management plans that are acceptable to farmers. Combining local control with budgets large enough to develop and manage complex programs and enforceable decision-making authority has allowed a variety of innovative resource conservation programs to be implemented to address local issues. For example, some of the NRDs have imposed mandatory agricultural water metering, reporting and groundwater pumping restrictions. Others have used land retirement and large-scale engineering projects to increase streamflows for endangered species and transboundary water obligations. Several NRDs run innovative water trading and nutrient management programs.

Nebraska's farmers are actively engaged in innovative water management through their participation in producers' groups and public-private partnerships. The **Nebraska Agricultural Water Management Network (NAWMN)**, which includes some 1,200 farmers and 1.7 million acres of land, is a collaboration between farmers, partners from the **University of Nebraska-Lincoln** and local, state and federal government agencies that tests water and energy conservation technologies and provides information, tools and education programs to interested parties. **The Nebraska Water Balance Alliance** is a farmer-led initiative that works with public and private sector partners to collect, share and analyze real-time data on water and other input-saving technologies and processes.

In combination with good groundwater management by the NRDs, research and adoption of agricultural technology, advanced crop genetics and varieties, and soil and water conservation practices have helped preserve much of the High Plains Aquifer throughout Nebraska, maintaining the state's groundwater near historically high levels.

The value of Nebraska's success in conserving its groundwater resources, and thus to irrigate effectively even when rainfall and surface waters are in short supply, became clear in 2012 when, despite experiencing its worst drought in nearly a half-century, Nebraska was able to draw on its groundwater reserves to sustain agricultural output levels on irrigated land. In the face of climate change and water scarcity in many agricultural areas, the NRD governance framework provides a model of good water governance and stewardship for future generations.

DROUGHT IN CALIFORNIA: YEAR 4



California is entering a fourth year of severe drought, which has forced 30 percent of cropland out of production in the past year. In 2015, the state's agricultural economy will lose $1.84 billion and over 10,000 seasonal workers due to the drought,[64] according to a report by researchers at the University of California, Davis. But the same report indicates farmers are showing resilience and are relying on groundwater resources to grow agricultural products. Groundwater has sustained the farm economy, but the reliance on these aquifers will require better resource management going forward, as some aquifers are nearing depletion. New state groundwater laws require local agencies to implement new management practices and to work with farmers to achieve more sustainable use of groundwater resources.

LIVESTOCK, NUTRITION AND THE ENVIRONMENT: A GLOBAL RESEARCH CHALLENGE

The growing demand for meat, dairy and other animal products by an increasingly affluent global population will require significant increases in animal agriculture research aimed at increasing productivity, quality and safety of animal food products while ensuring optimal animal welfare and environmental sustainability. Productivity enhancements in livestock farming and processing have been made feasible by a sustained commitment to public-funded research. Accordingly, research and development is key not only to ensuring this innovation continues, but also that it is extended globally.

Animal agriculture accounts for 60 to 70 percent of the total agricultural economy of the U.S. and contributes $43 billion annually to the U.S. agricultural trade balance.[65] However, over the past 20 years, **public funding of animal science research has been stagnant in real dollars and has declined in relation to the research inflation rate** (which is higher than for regular economic goods and services.[66]) Outbreaks of livestock diseases in the U.S. such as avian influenza, as well as mounting challenges from drought and environmental impact of livestock production, call for a more powerful leadership role by the U.S. public and private-sector animal science research community.

A major study by the **National Research Council** in January, 2015, provides a set of recommendations for reinvigorating the research agenda for animal agriculture.[67] Among the report's recommendations for U.S. policymakers and the agricultural industry:

» Provide **funding for integrative research** that can make an impact along the entire food chain, rather than individual components of the chain, and **restore public funding to past levels of real dollars and maintain this rate to meet the annual rate of research inflation**.

» Support **inter-disciplinary** and **public-private collaboration** for animal productivity and sustainability.

» Rebuild the **human** and **physical research infrastructure**.

» **Close the communication gap** between consumers, researchers and food industries around animal agriculture.

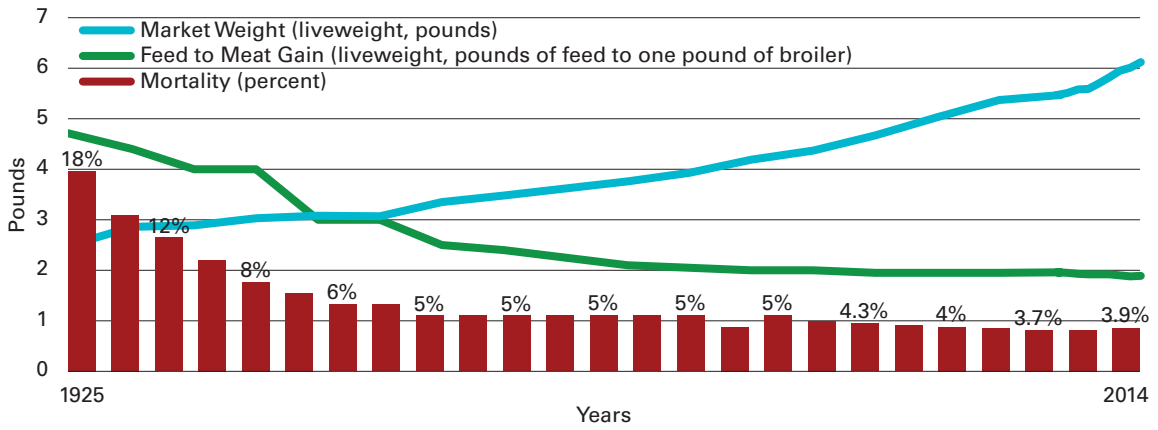
» Expand U.S. involvement in research to aid the **development of internationally harmonized standards, guidelines and regulations covering trade** in animal products and protection of consumers of those products.

» **Support and help coordinate global research activities** related to technology transfer, extension, and national policies to help developing countries sustainably meet their rising demand for animal products.

PRODUCTIVITY IN U.S. POULTRY BROILERS

Since 1925, U.S. poultry broiler mortality has declined from 18 percent of flocks to 3.7 percent today, while the weight of the average broiler increased from 2.5 pounds to just over 6 pounds and now uses less feed per pound of broiler. These improvements are the result of research and adoption of breeding technologies and better genetics, research into poultry nutritional needs and development of better feeds at lower environmental impact, as well as use of poultry health products and care practices that protect birds from disease.

Figure 22: U.S. Poultry Broiler Trends, 1925–2014



Source: National Chicken Council.

CONFRONTING THE WORST ANIMAL HEALTH EMERGENCY IN U.S. HISTORY

Avian influenza (Highly Pathogenic Avian Influenza), known also as HPAI, spread rapidly across the U.S. in 2015, resulting in the death of nearly 50 million turkeys and chickens throughout the Midwest. The outbreak hit 15 states, with Iowa, Minnesota and Nebraska losing the most birds, and caused economic loss of $3.3 billion. Poultry and egg barns required disinfecting and farmers must now restock their flocks after catastrophic losses.

The impact of HPAI has been felt across the entire economy, increasing the price of eggs because most affected birds were egg laying hens and turkeys. Additionally, trade has been reduced with some countries concerned about the devastating effects of this disease, directing more than $1 billion in poultry products to other markets, all at a cost to farmers.

When the outbreak began, USDA and the poultry industry responded rapidly to help farmers identify threats, increase biosecurity practices and dispose of infected birds. Biosecurity practices require that farmers keep poultry separated from wild birds and visitors, and maintain high standards of cleanliness in the barns. Good biosecurity practices also call for monitoring of birds to recognize and act on early signs of illness to prevent further spread of the disease and further losses.

Preventing future outbreaks will require additional research by USDA in partnership with farmers and agribusinesses. A key goal is the development of commercial vaccines for avian influenza. USDA must also engage with trading partners to assure them that poultry products will be safe to export and consume.

FUNDING U.S. RESEARCH FOR INNOVATION

If public agricultural R&D spending in the U.S. remains constant (in nominal terms) until 2050, the annual rate of agricultural TFP growth will be cut in half — from today's average of 1.5 percent to under .75 percent — and U.S. agricultural output will increase by only 40 percent over that time.[68] To make up for the lost productivity (as measured by TFP), raising output would require bringing more land, capital, materials, livestock and labor into production. But if policymakers increase public agricultural R&D resources, and mobilize additional private-sector and foundation resources to increase spending by 3.73 percent annually (thereby offsetting the historical rate of research inflation), the U.S. would be able to increase agricultural output by 73 percent by 2050 through improved productivity, using less land, livestock and capital.[69]

USDA's **Agriculture and Food Research Initiative (AFRI)** is the largest federal research program providing competitive grants to researchers to solve pressing challenges facing farmers and society. Congress provided AFRI with $262 million in funding for 2010, and annual funding has grown steadily to $316 million in 2014. The 2014 Farm Bill has authorized up to $700 million per year through 2018, but Congress has not provided the fully authorized annual funding levels for AFRI.

The 2014 Farm Bill also provided mandatory funding of $200 million to establish the **Foundation for Food and Agriculture Research (FFAR)**, a nonprofit corporation that supplements USDA's AFRI funding activities. FFAR will encourage public-private research partnerships, mobilizing matching funds from private sector and major foundations to leverage up to $400 million yearly. FFAR will complement the work that USDA is already conducting, as well as bring wider attention to critical needs, leverage private funding and attract new talent to the scientific research pipeline. Initial proposals for research are expected to be announced by December 2015.

FARM SMART AND CONSERVE SMART: PRECISION AGRICULTURE AND PRECISION CONSERVATION

Precision agriculture is the use of data and technology to increase the productivity and profitability of agricultural systems by applying inputs (fertilizers, pesticides, water, labor and machine hours) in precise amounts with maximum effectiveness. Through the use of equipment such as in-field monitors, GPS (Global Positioning System) navigation and tracking for machinery and cell phones, farmers can connect to and remotely manage many critical aspects of their farms. All data is linked back to the operator office, where it is stored to be used as a reference for following years. Farmers are able to precisely apply inputs they use in order to maximize their effectiveness in increasing yields and productivity.

Precision agriculture systems for crops, livestock, aquaculture, dairy and orchard operations continue to spread as technology improves and is more widely adopted by farmers in the United States and around the world.

- **GPS navigation and tracking systems** allow farmers to keep track of their equipment (location, hours of operation, maintenance issues, etc.) and use it more efficiently.
- **Machinery equipped with precision systems** of parallel steering, GPS and data history allows farmers to ensure that they cover every inch of the field and

avoid even the slightest overlap. This saves time, fuel and inputs while reducing the wear on the equipment. Each of these reductions improves the farmer's return on investment. Precisely applied inputs also help to minimize potential environmental impacts of farms.

» **In-field sensors** monitor and record data (on temperature, humidity, rain and wind) and send it to the farmer or service provider to generate models that can help minimize loss of inputs due to immediate rain, and to reduce other operational inefficiencies.

» Once the crops are planted, **crop monitors** will be able to sense and record the growth stage and health of the plants, reporting any possible pests, diseases or nutrient deficiencies. This will reduce the amount of labor needed to ensure optimal plant growth and generates data that can be tracked across growing cycles.

» Remote sensing is widely used today with satellite imagery and fixed wing aircraft collecting data for agriculture applications. **Drones** will be used to fly over each field and generate a map of the area, identify any potential weak points, assess crop health and report back to the farmer.

» **Yield monitors** record the quantity of the harvest across a field and produce a map of the high and low-yielding spots. This helps farmers address these spot problems, and improve the overall production of each field for future years.

» **Livestock monitors** can check individual animals for breeding cycles, feeding behaviors and injuries/diseases. This can help to notify farmers and ranchers of potential problems before they spread to the entire herd. Monitors also record how much food and water each animal consumes, track how much they are walking each day, and check them for lameness through video analysis.

» For **aquaculture** production, underwater sensors monitor temperature, salinity, oxygen content and nutrient levels to monitor fluctuations and to improve fish health and productivity.

USDA NRCS Soil Conservationist uses a Global Positioning System (GPS) and a personal digital assistant (PDA) to record natural resource data in Iowa.

FARM SMART, CONSERVE SMART

While precision agriculture allows farmers to write prescriptions for each field to select the right seeds to plant, apply the right amount of inputs, monitor the results and then adjust accordingly, the same technologies can also be used to better direct and guide conservation decisions. Welcome to the era of precision conservation. The ability to design a field-by-field conservation prescription will change the relationship between production and conservation. Farmers can make the two compatible and harmonize their results.

With the right information, farmers can see more clearly which areas of the field simply do not produce a profit — regardless of the inputs or use of price support programs or crop insurance. The question then becomes: why plant these areas at all? If farmers identify which portions of a field consistently produces a profit and which do not, why not retire less productive areas, plant them in habitat or some other conserving use, and then maximize production on the best acres?

The next generation of conservation programs will provide producers with the information — and the incentives — to answer that question. Farming "fencerow to fencerow" will be replaced by "farm smart; conserve smart."

What broad-based infrastructure is needed for precision agriculture to become more widely adopted and harnessed?

While the USDA and the Federal Communications Commission (through its Connect America Fund) have continued to fund the extension of broadband services to rural communities, there also needs to be a focus on reaching farmers and ranchers and enabling them to better connect within their own farming operations and with global markets in real-time.

» To take advantage of precision agriculture, farmers need to be able to collect data from monitors and equipment across large farms, so **broadband access needs to be farm-wide**. This means that **high-speed broadband service** needs to be extended across rural areas. Specifically, **farmers need access to high-quality, high-speed fixed broadband and mobile cellular coverage throughout the farms and associated cropland** — not just in offices and homes.

» **Policies are needed to achieve the twin goals of protecting farmer data and, at the same time, assuring it can be widely shared in order to advance precision agricultural and conservation goals**. Most farms will want to share the data with a company or program to analyze it, further complicating the ownership of the data, which is a legitimate farmer concern. Analytic companies need to work with policymakers and farmers to create solutions that will keep farmers' operations secure while opening data for analysis to maximize its potential to help individual farms and regions.

» **Farmers and services providers must collaborate to develop and test new technologies together**. Since the technology continues to develop, farmers and grower partners like **John Deere** and **The Climate Corporation** are engaging closely to learn what works well for farmers' operations and what doesn't.

AGRICULTURAL BIOLOGICALS: NEW SOLUTIONS FROM NATURE

Long before humans started to understand agriculture, plants were tending their own "crops": tiny flocks of microbes. Plants and microbes have existed in a mutually beneficial way for millions of years. **Agricultural biologicals** consist of microbes (tiny organisms like bacteria and fungi) that live in the environment and interact with plants, soil, animals and people in helpful ways.

Microbes put plant waste to work, converting it into vital nutrients and allowing plants to grow to their full potential. Microbes also improve soil quality and help plants become more resistant to stressful conditions such as cold and dry weather. Microbes are critically important to the modern farmer, who has the challenge of increasing the world's supply of food on a decreasing amount of arable land. This issue is compounded with weather shifts associated with climate change and an ever-increasing population. Sustainable microbial technology can help farmers meet this challenge.

Through extensive scientific testing, selected microbes are harnessed to improve plant health by enhancing growth or combating diseases and pests. These products serve as inoculants, helping plants absorb nutrients and protect against pests, disease and weeds. Agricultural biologicals are now being applied to a wide range of crops, such as alfalfa, canola, corn, chickpea, dry bean, lentil, mustard, pea, soybean and wheat. High-value crops such as salads greens, strawberries and nuts also benefit from their use.

In 2014, **Novozymes**, a global leader in science and sustainability, and **Monsanto** formed the **BioAg Alliance**, a long-term strategic initiative to develop new agricultural biological products and expand the research and commercialization of a new generation of microbials to help farmers meet world demand for food and feed in a sustainable way.

Novozymes scientist testing plant growth and yield. Photo Source: Novozymes

One such challenge is to ensure that valuable phosphate fertilizer is used efficiently by crops. Fertilizer can bind itself to soil particles, causing up to 90 percent of applied phosphate fertilizer to go unused in the year it is applied. In response, many farmers have to spend time and money to re-apply fertilizer.

A naturally occurring soil fungus *(Penicillium bilaii)* has been shown to release soil-bound phosphorus and convert it back to a form that the plant can use for growth. This fungus has been developed into a product called JumpStart® that helps plants get the most out of the fertilizer, and generates a higher yield potential of 4 to 6 percent. JumpStart® also increases root growth of crops by an average of 30 percent, resulting in better stress tolerance, helping plants take up water effectively and protecting them against dry conditions.

Agricultural biologicals are part of a growing toolbox of solutions that not only help improve yields for crops, but can also reduce the environmental impact of production and can contribute to sustainability.

(BIO)FUELING THE ECONOMY

Advances in biological research and development are propelling agriculture in new directions, providing cleaner fuels for production and transportation activities. Through agricultural science, biofuel crops are developed with higher yields and the right qualities that transform them to readily available renewable energy without impacting food supplies. Switchgrass, soybeans, sweet sorghum, corn, jatropha and algae serve as "feedstocks" (the materials used for energy). The products and byproducts of these crops create fuel substitutes that replace a portion of petroleum-based fuels, reducing carbon emissions while adding jobs for rural Americans.

Biodiesel is a successful example of how agriculture is providing cleaner fuels, particularly for freight and transport uses, while first meeting the world's need for food and livestock feed. Diesel is the prime fuel for powering farm machinery and tractors and for transporting agricultural products. Biodiesel is better for the environment because it is made from renewable resources and has lower emissions compared to petroleum diesel. It is less toxic than table salt and biodegrades as fast as sugar. Biodiesel is made from rapidly renewable sources such as soybean oil, animal fats, used cooking oil, and even new sources such as algae.

All diesel engines can use biodiesel without modification, and biodiesel can be blended with petroleum diesel to create a biodiesel blend. In 2014, U.S. biodiesel production reached 1.7 billion gallons, powering cars and trucks, farm machinery and equipment, buses, rail engines and boats.[70]

AGRICULTURE CAN HELP MITIGATE CLIMATE CHANGE

Agriculture and forestry production is the source of almost a quarter of global greenhouse gas (GHG) emissions. The majority of agricultural emissions are due to deforestation and conversion of forests to agricultural land, inefficient crop and livestock production, and poor soil management.

Farmers, ranchers and forest managers can use proven conservation practices and innovative technologies to reduce their GHG emissions. Policy and financial incentives can encourage these practices and enable agricultural producers to mitigate climate impacts quickly and effectively. Scientific studies show that **by adopting mitigation practices and embracing greater agricultural productivity, the agriculture and forestry industries will be able to reduce net emissions to half of current levels by 2050 while still increasing productivity for global food and agriculture needs**.[71]

Agricultural mitigation centers on reducing emissions of CO_2 (carbon dioxide), CH_4 (methane), and N_2O (nitrous oxide) from agricultural production; storing or sequestering carbon in forests, cropland and rangelands; and substituting fossil fuels with agricultural-based and waste-based fuels, such as biodiesel and biofuels. Practices include improving crop and grazing land management (particularly nutrient, soil and water stewardship), reducing deforestation and improving productivity to reduce the amount of land and number of animals required to meet needs.[73]

As mitigation strategies are put into action, the net CO_2 emissions from agriculture and forestry systems are expected to decline, eventually absorbing more carbon than it will release by the end of the 21st century.[74]

MANDATORY AND VOLUNTARY CARBON MARKETS

Greenhouse Gas (GHG) emissions trading systems are being used in the United States. **California's Global Warming Solutions Act (AB-32)** creates a **mandatory system** which sets emission allowances for each company and reduces that level each year. Through a cap and trade system, companies can buy and sell allowances, generating incentives to finance cleaner technologies. Protocols for reducing agricultural emissions have been established (such as the capture and destruction of methane from dairy and swine operations) that, when used by farmers, generate offset credits that can be traded. More agricultural offset protocols are expected, including for rice cultivation.

Several voluntary GHG registries operate in North America, and many of these registries have developed and approved agricultural offset protocols and methodologies. Voluntary registries that have approved agricultural offset protocols and methodologies include the **American Carbon Registry (ACR)** and the **Climate Action Reserve (CAR)**. Another North American voluntary GHG registry, **The Climate Registry (CR)**, tracks member company GHG emissions or carbon footprints but does not currently have verification standards for offsets, though it may allow offsets to be reported by member companies.[72]

Offset protocols include reducing nitrous oxide emissions through fertilizer management, avoiding conversion of grasslands to crop production, grazing land and livestock land management, adding compost to grazed grasslands, and reducing GHG by installing a manure biogas control system for livestock operations.

AGRICULTURAL PRODUCTION PRACTICES THAT REDUCE GHG EMISSIONS

Cropland technology and management: Improved crop genetics and conservation practices increase yield and reduce the amount of land required, slowing the conversion of land to crop production.[75] Certain GM (genetically modified) crops contribute to reduced fuel since they require less frequent herbicide or insecticide applications, decreasing the need to use machinery and the energy that fuels it.[76] Crop management practices, particularly rotations with legumes (to fix nitrogen), allow soils to store carbon and soil organic matter and improve soil quality. Cover crops that provide ground cover preserve soil quality, carbon sequestration, water-holding capacity and support nutrient cycling and availability.

Growing More, Emitting Less

Between 1961 and 2005, research has shown that total crop yield increased by 135 percent but global cropland grew by only 27 percent. This net effect of higher yields, mostly from cereal and oilseed crops, has avoided unnecessary deforestation and emissions of 590 gigatons of CO_2 ($GtCO_2e$) or 13.1 gigatons of CO_2 annually,* an amount equivalent to preserving 100 million acres of forest each year. **Without these yield improvements, global GHG from agriculture would have more than doubled**. Investments in seed genetic improvements and the dramatic increases in yield have translated to a mitigation cost of approximately $4 per ton of CO_2 emission, which compares favorably with other mitigation strategies.

**Burney, Jennifer A., Steven J. Davis, and David B. Lobell. "Greenhouse gas mitigation by agricultural intensification." PNAS, Vol. 107, No. 26, (June 29, 2010).*

Nutrient management: Nitrogen in fertilizer and manure can be a major source of both GHG emissions and pollution. When managed properly, fertilizers can be used efficiently and precisely to prevent over-application and waste. Strategies include precision application, maintaining high-quality soil through conservation practices and crop rotations, using slow release fertilizer and improving fertilizer application timing for best uptake.

Tilling management: Reduced or no-till systems reduce erosion, soil degradation and loss of carbon stored in the soil, and reduce the costs of farming, maximizing returns on investment for the farmer. Improvements in farm machinery, in combination with high yielding, herbicide-tolerant GM crops, have made it possible to use these systems more easily.[77]

Water management: Precision irrigation ensures efficient and productive use of minimal amounts of water. By applying water exactly when and where it is needed, farmers can make the most of smaller amounts of water while improving yield, productivity and carbon uptake in the soil.

Rice management: The high methane emission rates of cultivated wetland rice soils during the growing season can be reduced by coordinating the timing of fertilizer applications with the dry instead of the wet season, draining wet fields during the wet season, and improving the genetic quality of rice cultivars.

Agroforestry: Combining the production of livestock or food crops on land where trees and timber are grown helps conserve carbon and nutrients in the soil, improves the profitability of tree lots by providing an annual income, prevents erosion and provides shade for animals.[78] Most of the potential for mitigation through agroforestry can be found in moist tropic regions.[79]

Grazing land management and livestock management: Grazing management includes several practices. A crucial factor in the health of the fields and the levels of GHG emissions is the amount of grazing. Both over-grazed and under-grazed pastures store less carbon than optimally grazed lands. There are many practices that can reduce methane emissions from ruminants such as cattle and sheep: improving feeding practices by reducing forage consumption, improving soil and feed quality in pastures, using dietary additives and optimizing breeding practices. Methane inhibitors added to feed are now being tested with the potential to reduce methane emission from ruminants by up to 30 percent without reducing animal productivity.[80] With improved genetics and care practices, animals produce more milk and meat per animal with reduced emissions.

Manure management: Animal manure storage produces large amounts of nitrous oxide and methane. By storing manure in cooled or covered lagoons or tanks and using methane digesters, emissions of GHGs into the atmosphere are reduced. Methane can also be captured and used as an energy source. Dairy farmers also reduce the amount of GHGs produced by the animals through diet and nutrient management, such as including protease enzymes in feed.

After products leave the farm: About half of emissions produced from the agricultural value chain come from post-production steps, including processing and transportation. These post-harvest GHG emissions can be reduced through renewable energy production and use, alternative fuel use such as biofuels, low-carbon design buildings, increased use of energy and fuel efficient vehicles, reduction of waste and application of life-cycle management of packaging materials.[81]

Reducing Poultry's Environmental Impact Through Enzymes

Addition of supplements to animal feed and modifying their feeding programs to improve nutrient efficiency can significantly decrease the nitrogen, phosphorous and manure matter of livestock, reducing GHG emissions and environmental impact of production. The **protease enzyme** enhances the uptake and metabolization of feed, enabling poultry to require less protein and help better utilize nitrogen. Studies have shown that nitrogen content of poultry manure can be reduced by up to 15 percent with the use of protease.[82]

The U.S. Dairy Industry Reduces its Carbon Hoofprint

Improving the productivity of dairy cows has also reduced their GHG emissions and environmental impact. Modern dairy production practices in the United States require considerably fewer resources now than in the 1940s, with 21 percent fewer animals, 35 percent less water use and only 10 percent of the land now required to produce the same 1 billion kg of milk.[83] Dairy waste has also been reduced, with modern systems producing only 24 percent of the manure, 43 percent of methane and only 56 percent of the nitrous oxide compared with equivalent milk production. As a result, the carbon footprint of milk production has been cut by two-thirds since 1944.[84]

MANAGING RISK AND BUILDING SAFETY NETS FOR AMERICAN FARMERS

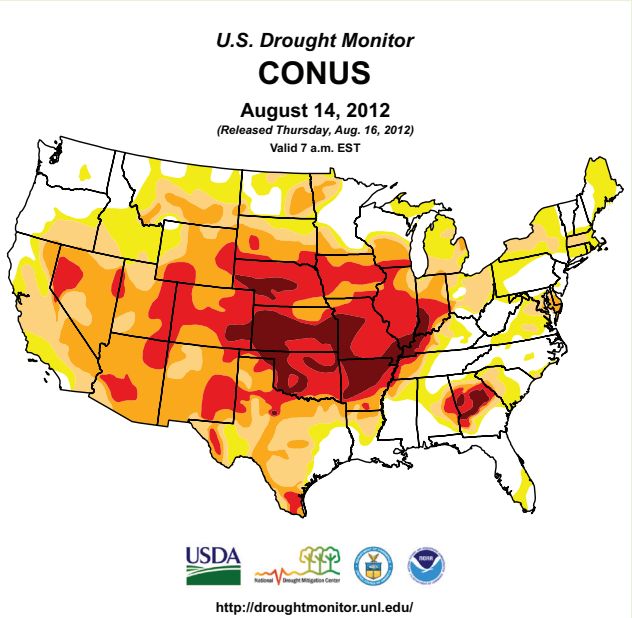
Agriculture is an inherently risky business. Farmers and ranchers face threats from drought, flooding, diseases and pests, as well as price volatility in world markets.

Good farm management practices, data and technology are fundamental for minimizing risks. As part of a risk management strategy, U.S. government and industry work together to offer a variety of products that farmers can use to protect against price drops, crop failures and other adverse conditions. The goal is to enable farmers to maintain an adequate profit margin so they can continue to supply food and other agricultural products that wider society needs and contribute to the local, regional and national economy.

Risk management increasingly requires that producers take a holistic approach, assessing interconnected factors within the entire agricultural value chain. Strategies for risk management include **purchasing crop insurance, diversification of products and markets, off-farm employment, vertical integration, contracting** and **hedging**. Access to state-of-the-art technology (precision agriculture systems, data, advanced crop seed and livestock breeds, crop protection, equipment for harvesting and storage) and good farm management practices also reduce risks to farmers and protect their operations.

THE DROUGHT OF 2012

The severe drought of 2012 that impacted large swaths of the U.S. Midwest could have forced farmers out of business and created ripple effects through the entire regional economy. A study by researchers covering four affected states (Iowa, Nebraska, South Dakota and Wyoming) showed that the crop insurance safety net system protected farmers' livelihoods, along with preserving 20,900 off-farm jobs.[85] Farmers had previously paid $885 million in insurance premiums to cover 54 million, or 85 percent of insurable planted acres, in the four state region. As the drought progressed during 2012, they received $4.482 billion in indemnity payments for the growing season (April 2012 through March 2013), allowing them to prevent heavy losses to their farm operations and to continue investing in the long-term viability of their farms. In addition to benefitting these farms, the crop insurance program preserved off-farm jobs that would have been lost in each of the four states, in cities as well as the rural areas.



U.S. Drought Monitor, August 14, 2012 shows extensive drought conditions

THE SAFETY NET OF INSURANCE

The 2014 Farm Bill reinforced risk management through insurance and conservation practices, rather than providing direct payments to farmers. Up until 1995, only about one-third of farmers bought federal crop insurance because in the event of a disaster they could generally rely on Congress to provide disaster assistance payments and emergency loans.

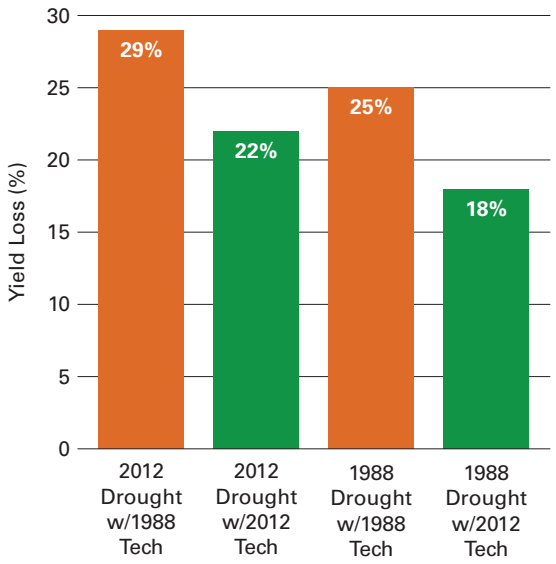
With the reforms in the **Federal Crop Insurance Reform Act of 1994** and further amendments over the years, farmers have access to the most effective risk management toolbox available, which provides a wide set of options and is provided through an efficient risk-sharing partnership between the federal government and private-sector insurance companies.

The **Federal Crop Insurance Program** is partially subsidized by the U.S. government; to qualify for insurance premium subsidies, farmers must be in compliance with conservation standards. **Federal Crop Insurance Corporation (FCIC)** programs are administered by the **USDA Risk Management Agency (RMA)**, which underwrites crop insurance policies for hundreds of crops and types of livestock. Crop insurance policies are sold and serviced by private insurance companies.

Insured farmers receive indemnity payments if their yield or revenue falls beneath a certain pre-specified threshold. Risks vary by farm operation and therefore insurance policies are tailored to specific risks, such as diseases or changes in milk prices for a dairy farm, or frost or hail damage for crop farmers.

With greater flexibility to insure a variety of crops and livestock against price volatility and weather losses, insurance participation has expanded to more acres, crops and producers than ever before while avoiding costly *ad hoc* disaster programs. Today more than 85 percent of the 10 major U.S. crops are insured under the **Multiple Peril Crop Insurance Program**. Crop insurance serves as a reliable guarantee for banks to lend money to the farming community, ensuring that farmers can continue accessing capital to improve their operations.

Figure 23: Crop Technology Protects Corn in Drought



Source: Neil Savage, "Modelling: Predictive Yield." *Nature*, 501. (September 2013).

The 2012 drought was worse than the drought of 1988, but had less impact on corn yields due to crop genetic advancements and best management practices.

Simulating the 1988 drought with 2012 technology produced a loss of only 18 percent, but if farmers had used 1988 technology during the 2012 drought, the losses would have exceeded 29 percent.

OTHER RISK MANAGEMENT STRATEGIES

Farmers have other strategies they can combine with insurance to meet their specific farming and risk needs. **Diversification of products** (such as growing maize, soybeans and raising poultry) helps reduce the risk of a large drop in price in one market, as unrelated markets are less likely to fall at the same time. Farmers can also **diversify geographically** by spreading their fields out to minimize impacts of storms or diseases.

Off-farm employment, such as a secondary non-farm related job, enables farmers to supplement their income. Due to the seasonal nature of farming in many areas, there are periods of time where a farmer would be able to pursue alternative employment. Secondary operators or spouses and family members are likely to work in a non-farm related job to augment the family income.

Vertical integration gives a farmer control of a product through several stages of production and processing, and can either use their products on their own farm again or sell the final product for a higher value. This can be expensive and usually requires more varied expertise.

Historically, most agricultural products were bought and sold for immediate delivery through "spot markets," but a growing share (40 percent in 2008, up from 11 percent in 1969[86]) of the value of U.S. farm output is produced and sold under **agricultural contracts. Production contracts** (in which the contractor owns the commodity and pays the farm operator to raise it) are widely used in livestock production, while **marketing contracts** (in which the farmer retains ownership of the commodity but promises future delivery to the contractor) are used for many crops. With both, the price for the product can be determined beforehand, or it can be based on the futures market price on a certain date. This gives farmers access to capital before the growing season and guarantees a certain payment. However, if the futures pricing option is not used and the market price rises, they will lose the difference between their contracted price and the market price.

"Finding the balance of market-based and government-supported risk strategies is critical for the producer to manage risk and seek a profit in order to stay in business."

~ Jeff Lakner, Lakner Farms, LLC
Wessington, South Dakota

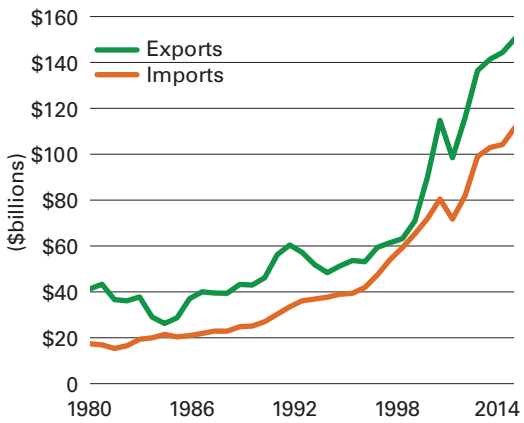
Hedging shifts the risk of the farmer (hedger) to a party that is willing to accept that risk (speculator or another hedger, such as processor). Such transactions are often pegged to or entered into through a government-regulated derivatives market, such as a futures exchange. For example, a farmer can protect against a decline in the price of her/his commodity by selling a **futures contract** at the beginning of or during the growing season, and then buying the futures contract as s/he sells the harvested commodity. Such transactions require margin payments and can be costly over time. Alternatively, the farmer can buy a **put option**, which gives the right, but not the obligation, to sell a futures contract up until the expiration date. For a relatively modest, up-front premium price, put options give the farmer price assurance without sacrificing the ability to take advantage of increasing prices. Farmers can use either future or options contracts to minimize the possible damage from a negative change in price in the market, and to protect crops in more than one crop year.

MOVING FOOD, FEED, FIBER AND FUEL TO MARKET — THE INFRASTRUCTURE IMPERATIVE

Countries that have efficient production combined with modern infrastructure and transportation systems can compete in the fast-paced and growing global marketplace. Ninety-five percent of the market for U.S. goods is outside the United States. As worldwide demand for agricultural products increases, U.S. farmers and aggregators must be able to supply food, feed and fiber to agro-processors and consumers across the nation and overseas.

In 2014, U.S. food and agricultural exports reached a record $150 billion, supporting more than 1 million jobs.[87] Exports grew by 8 percent on average annually from 2000 to 2014, while imports increased by 7.8 percent. As a result, the U.S. agricultural trade surplus widened to $38.8 billion in 2014.[88]

Figure 24: U.S. Agricultural Trade, 1980–2014



Source: Data compiled by USDA FATUS, Calendar Years 1980-2014.

A TRANS-PACIFIC PARTNERSHIP FOR TRADE

The **Trans-Pacific Partnership (TPP**) is perhaps the most important trade negotiation taking place in the world today. With a potential market of nearly 800 million consumers, the combined economic output of the 12 countries involved accounts for about 40 percent of world GDP. Negotiations started five years ago with completion anticipated in 2016. Finalizing this agreement could boost total U.S. goods and services exports by an additional $123.5 billion per year from 2016 to 2025, providing real income benefits estimated at $77 billion annually.[89]

For the 12 participating countries, the TPP agreement would increase market access — thereby expanding trade volumes — and strengthen environmental and labor standards. An important breakthrough is the establishment of a more coherent process for addressing agricultural sanitary and phytosanitary import barriers that are not based on scientific evidence and serve as impediments to international trade.

USDA estimates that due to greater market access, the value of U.S. agricultural exports to TPP partners in 2025 would be 5 percent ($2.8 billion) higher than without the agreement, increasing output for many agricultural sectors and particularly for cereals, dairy and meat.[90] The successful conclusion of the TPP agreement would also lay the groundwork for completion of the **Trans-Atlantic Trade and Investment Partnership (T-TIP)**, another major trade agreement currently being negotiated between the United States and the European Union.

It takes well-constructed, properly-maintained and interlinked infrastructure to move goods to markets efficiently, while conserving freshness, quality and safety of food and other agricultural products. With its large geographic area and long distances from rural production areas to markets, the United States has a high level of freight activity. Anticipating booming global demand for food and agricultural goods that will occur in coming decades, modernization and maintenance of this infrastructure and the transportation network is critical for ensuring smooth functioning agricultural value chains and expanded trade capacity.

Unfortunately, U.S. government infrastructure investment is already lagging behind: it is less than 2 percent of GDP,[91] the lowest level since World War II.[92] Other countries are investing more as a percent of GDP: Canada invests 4 percent,[93] Mexico 4.5 percent,[94] Europe 5 percent,[95] India 8 percent[96] and China 9 percent.[97]

Aging U.S. port terminals are not equipped to handle multiple ships holding 8,000 to 14,000 20-foot containers per vessel, which is common with today's large ocean-going cargo ships. Outdated and insufficient infrastructure, poor connectivity to rail and highway networks, and inefficient operations created massive congestion in 2014–2015 at West Coast ports, slowing and at times halting the delivery of cargo. Without immediate investments to modernize and upgrade these systems and to handle larger ships and the growing amount of trade, the situation will worsen. Labor disputes also can slow down the export of goods, resulting in waste and loss of food and agricultural products and disruptions to market supply for customers across importing nations.

Navigable inland waterways have traditionally been the low-cost means of moving agricultural and food products within the United States. Barges on the Mississippi River system move cargo from the upper Midwest and center of the country to southern and eastern states and ports. But that system has become less reliable as the 1930s, locks and dams along the Illinois, Mississippi and Ohio Rivers have deteriorated, making it difficult and more expensive to move agricultural and food products.

At the same time, roads and railways that allow trucks and railcars to quickly move agricultural goods are in need of repair and modernization. The American Society of Civil Engineers estimated that U.S. surface transportation infrastructure faces a funding gap of about $94 billion a year.[98]

Solutions must be found to increase investment levels for all modes of transportation infrastructure. Funding must strategically target not only various parts of the system (road, rail, waterways, locks, dams, and ports), but also the transportation bottlenecks that occur at intermodal connections, where multiple modes of transport come together. Transportation experts and private industry leaders have called on Congress to advance a number of critical investment mechanisms that can help mobilize funds to target the infrastructure improvements.[99] These include:

» Reauthorization of the multi-year surface transportation funding bill, **Moving Ahead for Progress in the 21st Century (MAP-21)**, which includes resources and reforms that are needed to maintain spending for transportation infrastructure. Presently the legislation has received short-term extensions to continue some infrastructure projects, but the lack of long-term certainty is preventing partnerships between federal, state and private-sector from moving forward.

» Authorization of a federal program providing **incentives and resources for competitive multimodal infrastructure** that would leverage additional funding from private and state partners.

» Continuation of robust funding for infrastructure improvements to inland waterways and ports, through the bi-partisan **Water Resources Reform and Development Act (WRRDA)**. Enacted into law in 2014, WRRDA provides funding and policy reform to improve water transportation networks, strengthens the safety of dams and levees along waterways, reduces risks from flooding and storms to transportation infrastructure, and helps fund dredging of ports so that larger ships can enter.

INNOVATIONS TO REDUCE HUNGER AND IMPROVE NUTRITION

Forty-nine million Americans, including 15.8 million children, live in food insecure homes and lack sufficient nutritious food. Paradoxically, obesity rates in the U.S. have soared in recent decades, particularly in low-income communities, due to a range of social and economic factors, as well as from increases in caloric intake and reduced physical activity. Individual and societal costs of hunger and obesity are profound. Hungry children will earn, on average, $260,000 less that than their peers over the course of their lives.[100] Treating obesity-related illness costs an estimated $190 billion per year, nearly 20 percent of all health care spending.

Today, U.S. food and health care industries, non-profit organizations and government agencies are applying their ingenuity to deliver better nutrition to malnourished Americans. Three emerging models are **financial incentives** that make fruits and vegetables more affordable for low-income consumers, **food prescriptions** to help **prevent illness and manage chronic disease** and **sophisticated data analysis** to make local food assistance networks more cost-efficient and sustainable.

Over the past decade, an increasing number of participants in the **Supplemental Nutrition Assistance Program** (**SNAP** — formerly called "food stamps") have been encouraged to use their benefits to purchase produce at farmers' markets, where they receive additional credit that can be spent on fresh fruits and vegetables with each purchase. The program has increased servings of fresh fruits and vegetables consumed by SNAP households and has had favorable impacts on farmers' sales.[101]

The 2014 Farm Bill established a $100 million, five-year **Food Insecurity Nutrition Incentive Program**, which provides matching funds for projects that incentivize the purchase of fruits and vegetables by SNAP beneficiaries. The **AARP Foundation** is partnering with **Kroger Co.** in Tennessee and Mississippi on an innovative model that gives SNAP customers who spend $10 on fresh fruits and vegetables a coupon for 50 percent off their next purchase of produce.[102]

Food "prescriptions" are an outcome of changes in U.S. public health policy, which now emphasizes healthy eating as a critical strategy for preventing illness and managing chronic disease. The **Affordable Care Act** incentivizes insurers to offer discounts for clients who adopt healthier lifestyle habits. Under this approach, health insurance reimbursement is provided for foods that are "prescribed" by doctors to prevent and/or address specific health care conditions. The Boston Medical Center's **Healthy Eating for at Risk Older Adults (HERO)** program provides individually-tailored food prescriptions for clients that are elderly, low-income or suffer from chronic physical and mental health conditions.[103] Case workers assess each client's needs and arrange the delivery of prescribed nutritious food on a weekly or bi-weekly basis. A six-month evaluation of the program showed improvements in key nutrition-related indicators, including weight, eating habits and food security.

In Indianapolis, Indiana, the **Indy Hunger Network (IHN)**, a coalition of non-profit and faith-based groups, government agencies and local companies is using Six Sigma[104] systems analysis to make the local food assistance system more cost-efficient and effective.[105] A data-generated map revealed the need for a better coordinated food pantry system so that hungry people could have convenient access to supplemental food. Data analysis also revealed that millions of federal assistance dollars for SNAP, WIC and school meals were going unused because people did not know they qualified or how to apply. IHN worked with local leaders to develop research-driven outreach strategies that increased registration for nutrition programs. Indianapolis-based **Elanco Animal Health** and its parent

company **Eli Lilly**, support IHN as part of their **Break the Cycle of Hunger** initiative by providing strategic leadership, financial support and employee volunteers. From 2010 to 2013, 40 million more meals were provided to hungry people in Marion County, thanks to the collaboration of IHN partners.

A HEALTHIER, SUSTAINABLE SUBSTITUTE FOR *TRANS* FAT

Over the last decade, consumers and producers have become more aware of the health risk of *trans* fat in foods. In 2015, the U.S. Food and Drug Administration announced that within three years all partially hydrogenated oils (PHOs), the primary source of artificial *trans* fat, must be removed from processed foods. Palm oil is considered an effective substitute for PHOs because it remains solid at room temperature and is *trans* fat free. The exponential increase in palm oil production has led to rapid deforestation in tropical countries such as Indonesia and Malaysia. The global demand for palm oil is estimated to double by 2050, putting even greater pressure on fragile ecosystems in Asia and Africa.

Agribusiness and food companies are developing PHO alternatives that are healthier and can also be grown sustainably with a much lower environmental impact. Oil produced from genetically engineered **high oleic soybeans** is stable at high temperatures and *trans* fat free. **DuPont Pioneer** and **Monsanto** have developed soybean varieties producing environmentally sustainable high oleic vegetable oils that are more stable and increase the shelf-life of products such as breakfast cereals and are ideal for food frying applications. High oleic oils reduce the saturated fat content of these foods relative to palm oil, without sacrificing taste. Given the skyrocketing demand for PHO substitutes in the coming years, the **United Soybean Board** predicts that by 2023, U.S. farmers will be planting 15–20 million acres of high oleic soybeans.

CONSUMERS IMPACT THE AGRICULTURAL VALUE CHAIN

A variety of public-private collaborations and policies have developed in response to rising consumer influence in the U.S. agriculture and food system, **particularly to reduce food waste and advancing fair wages and working conditions for agricultural workers.**

WASTE NOT, WANT NOT

In the United States, **133 billion pounds of food — 30 percent of the total food supply — is wasted during the production and consumption stages**. This includes 87 billion pounds of nutrient-rich foods such as meat, eggs, fish, dairy products and fruits and vegetables.[106] That amounts to **141 trillion calories (1,250 calories per person, per day) that wind up in trash cans and landfills** at a time when 49 million Americans (including 15.8 million children) are food insecure.[107]

For food companies, minimizing waste is critical to their bottom line, but most U.S. consumers have little financial incentive to reduce the amount of food they waste. On average, American consumers spend just 6 percent of their disposable income on food, the lowest rate in the industrialized world, and waste 21 percent of the total annual food supply. Despite the high rate of consumer food waste, the cost to the consumer is roughly $1 per day ($371 per year) — for many, an insufficient inducement to change their behavior.[108]

USDA is raising awareness and providing consumers with tools to reduce food waste. The **FoodKeeper** mobile phone app, developed by **USDA**, the **Food Marketing Institute** and **Cornell University**, helps consumers decipher "best by date" labels by providing access to clear, scientific information on food storage, proper storage temperatures, food product dating and expiration dates.

Food retailers reduce food waste by donating safe unsold food to charitable organizations. Food that is no longer fit for consumption often ends up in landfills or incinerators, where it contributes to greenhouse gas emissions. But growing numbers of grocery stores, including **Wegmans** and **Stop & Shop**, are using food waste for clean, renewable energy. In 2014, Wegmans employed anaerobic digesters to convert more than 2.5 million pounds of food scraps into biogas and electricity, avoiding methane emissions at landfills.[109]

ADVANCING FAIR WAGES AND SAFE LABOR CONDITIONS

Agriculture in the United States relies on millions of hired farm laborers, many of whom are immigrants, to cultivate, care for, harvest and process a variety of plant and animal products. These workers face a wide range of environmental risks to their health and safety. There are fewer regulations regarding overtime pay, minimum wage and child labor in agriculture than in other industries. Many farmworkers have low levels of education and limited access to insurance and social benefits. Often they are afraid to assert their basic rights due to their language barriers and immigration status. According to the USDA and the U.S. Department of Labor, agricultural workers are "among the most economically disadvantaged working groups in the United States."

Thanks to a growing number of socially responsible producers and consumers, agricultural working conditions are improving in some notable cases. Advocacy organizations and consumers are using their pocketbook power to bring about higher wages and safer working conditions for farm laborers.

The Coalition of Immokalee Workers' (CIW) Fair Food Program is widely recognized as the country's most effective agricultural workplace monitoring program. This unique partnership between farmers, farmworkers and retail food companies strives to ensure fair wages and humane working conditions for the workers who pick fruits and vegetables on participating farms. The Fair Food Program gives farmworkers a voice in the decisions that affect their lives and works to eliminate the abuses that have plagued agricultural workers.

Workers are educated by CIW on their rights and they are able to report any violations to a worker complaint hotline, which initiates a quick investigation and resolution of the problem. Growers are audited by the Fair Foods Standards Committee, which inspects working conditions, interviews farmworkers and management, and reviews payrolls and timesheets. The involvement of the large number of farmworkers as monitors and enforcers makes the system more responsive to worker's concerns.

Participating growers agree to increase wages, comply with the Fair Food Code of Conduct, allow time and space for worker education sessions and undergo comprehensive audits. Buyers who participate in the Fair Food Program agree to only buy from growers who abide by the regulations and to pay a Fair Food Premium above the standard price for the products they purchase. This price premium is used to improve wages for farmworkers; nearly $15 million has been earned since 2011 in the Florida tomato industry alone.

Volunteers and L.A. Kitchen trainees work side by side to prepare 3,500 fruit parfaits for Special Olympics. Photo source: Robert Egger LA Kitchen.

NEITHER FOOD NOR PEOPLE SHOULD EVER GO TO WASTE!

Founded in 1989, **DC Central Kitchen (DCCK)** is the premiere model for reducing hunger with rescued food, training unemployed adults for culinary careers, serving healthy school meals and rebuilding urban food systems through social enterprise. In 2013, DCCK founder, Robert Egger, moved to Los Angeles at the invitation of the city's mayor, to launch **LA Kitchen (LAK)**.

LAK has a multipronged mission of reducing food waste and unemployment while combating hunger. The primary components of the model include food rescue (Reclaim LA), culinary job training (Empower LA), volunteerism (Engage LA), food distribution (Nourish LA) and social enterprise (Strong Food). What makes LAK stand out is its focus on fresh produce, vegetarian and vegan offerings, as well as its emphasis on older adults.

AARP Foundation became the official founding funder of LAK. Even before it had an official home, LAK launched Empower LA, its culinary arts class for unemployed and at-risk youth and older adults, and has since graduated three classes (many of whom would otherwise be considered "unemployable") with a 75 percent job placement rate. Strong Food, LAK's revenue generating subsidiary, is actively competing for and winning food service contracts and producing value-added wholesale and retail products from locally sourced fruits and vegetables.

In less than two years, LAK has grown into a thriving operation supported by multiple foundations, food service contracts, celebrities and community members across the city of Los Angeles — all of them recognizing that **neither food nor people should ever go to waste**.

BUILDING A SUSTAINABLE BREADBASKET IN ZAMBIA

Zambia's natural resource base, stable government and investor-friendly policies make it a potential breadbasket for southern Africa. **Zambian producers are a testimony to its agricultural promise.** The country's large-scale farms are some of the most productive in Africa and an emerging class of medium-scale farmers is contributing to the agricultural value chain. Innovative public-private partnerships in maize, livestock, groundnuts and horticulture production are raising farm incomes and increasing food security. Small-scale farmers are protecting their soils and increasing yields thanks to improved hybrid seeds, fertilizer, mechanization and conservation farming techniques.

Successive Zambian governments have looked to agriculture to grow and diversify an economy that is heavily reliant on volatile global mineral markets. As a participant in the **African Union's Comprehensive African Agricultural Development Program (CAADP)**, Zambia has committed to increase its annual expenditures for agriculture to 10 percent of its budget.[1] Allocations for agriculture increased to 9.3 percent in 2015,[2] nonetheless the value added by agriculture to Zambia's GDP remains in the 7 to 10 percent range and rural poverty rates (those living on less than $1.25/day) are stubbornly entrenched around 80 percent.[3] Furthermore, decades of underdevelopment have left Zambia's agricultural value chains vulnerable to environmental shocks and changing climate patterns.

Zambian producers want the knowledge, resources and opportunities to make their enterprises more productive, profitable and resilient. **Prioritizing agricultural investments that stimulate the productivity and sustainability of Zambia's large and diverse groups of producers is therefore essential.** Globally, the total amount that producers invest in their own operations is three times larger than the investments made by governments, development agencies and foreign investors.[4] But with an average agricultural capital stock per worker of less than $2,000, most Zambian farmers are undercapitalized, making it difficult to invest in productivity-enhancing and labor-saving technologies.[5] The UN Food and Agriculture Organization (FAO) estimates that **60 percent of the additional investment needed to improve the productivity and livelihoods of poor, undercapitalized producers needs to come from the public sector.**[6]

By examining Zambia's agricultural "architecture" — including land and water access; conservation practices; mechanization, seed and fertilizer usage; infrastructures for finance, transportation, power and communications; research and extension systems; and regulatory environments for market development and trade — **the 2015 GAP Report identifies strategies, policies and partnerships that can help Zambia build a sustainable breadbasket for southern Africa.**

- Ensure that farmers of all scales, particularly women, **have access to land tenure, as well as productivity-enhancing and labor-saving inputs**.
- **Extend and improve the infrastructures** for transportation, electricity and irrigation, as well as access to financial systems and telecommunications networks.
- **Invest in research and extension** to develop and transfer agricultural knowledge.

» **Reduce bureaucratic barriers and harmonize regulations** to increase trade and market development.

» **Scale-up social protection programs** to improve food security, reduce malnutrition and stabilize incomes.

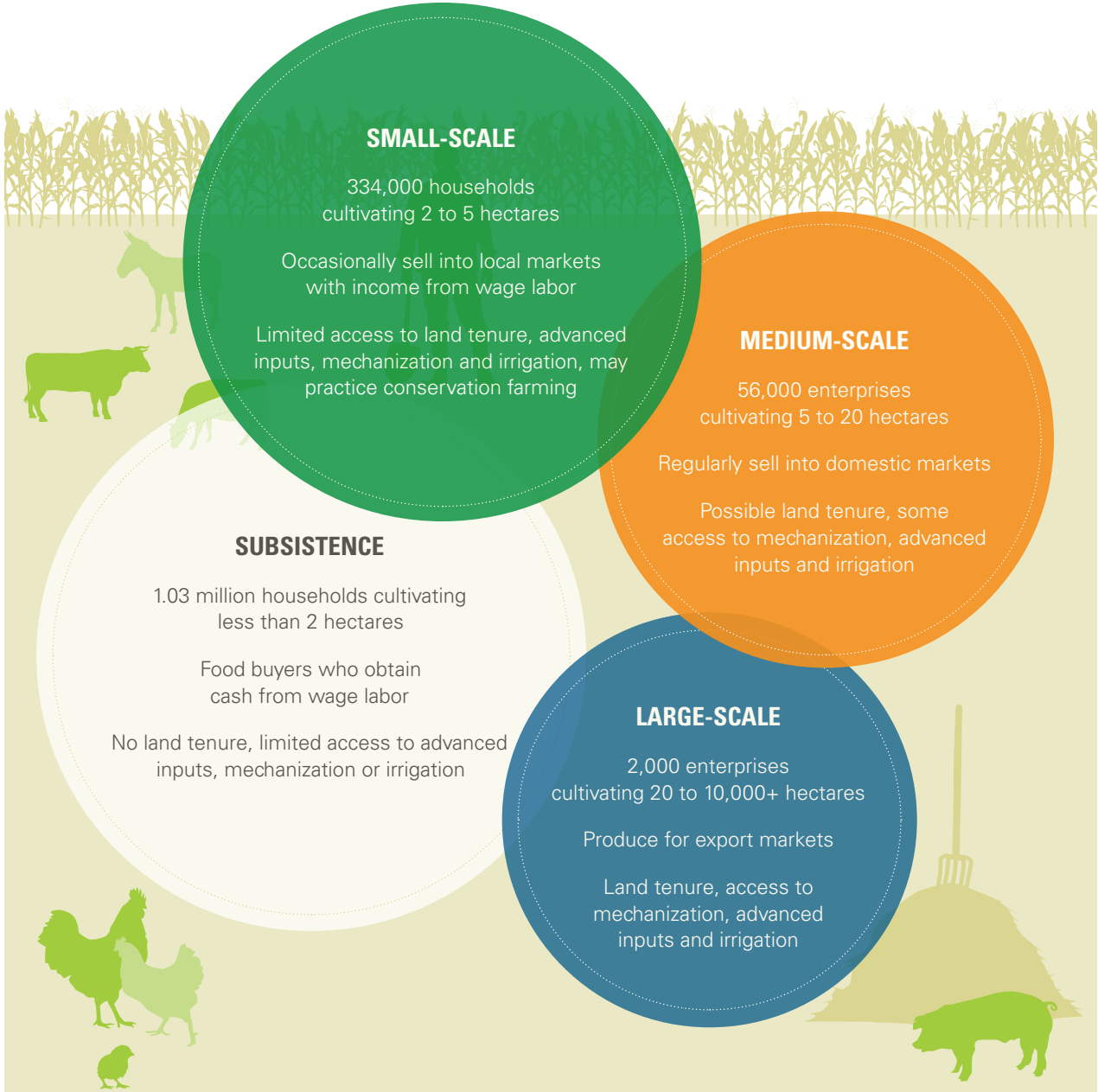
GHI's five policy priorities create an enabling environment that fosters investment and innovation across the agricultural value chain. **Case studies** from the Global Harvest Initiative's *Member Companies* and *Consultative Partners* **demonstrate how these investments are making Zambian agriculture more productive and sustainable.** Accompanying each case study are icons representing the policy goals that contribute to their success.

ZAMBIA'S PRODUCERS[7]

In Zambia, 70 percent of the economically active population work in agriculture. Ninety-six percent of farmers cultivate fewer than 5 hectares of land. Zambia's **subsistence farmers** are net food buyers and derive their income from agricultural and non-agricultural wage labor. **Small-scale farmers** receive a portion of their income from selling into local markets, yet they are still net food buyers and rely on wage labor income.

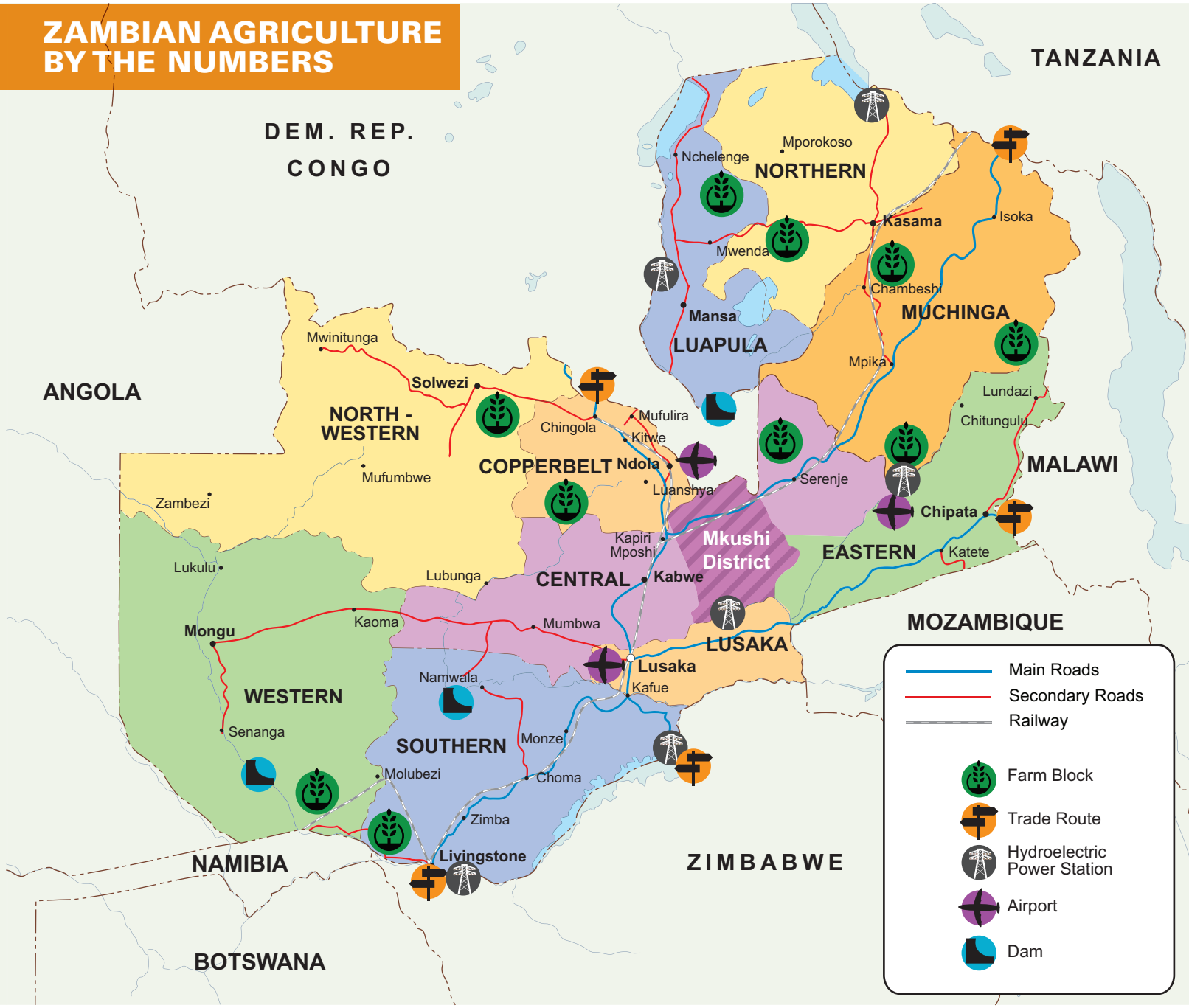
Zambia is also home to an emerging class of **medium-scale farmers** who produce crops primarily for internal markets and are more likely to have tenure and use advanced inputs. **Zambia's large-scale farmers** produce for export markets, operating with comparable inputs and technologies to farmers in the American Midwest.

The typical Zambian small-scale farmer cultivating 5 hectares grows maize (3 ha), sunflower (.5 ha) and groundnuts (.5 ha), and may rear some combination of cattle, goats, pigs and chickens. A typical large-scale producer with 1,050 hectares plants soybeans and maize (350 ha) and wheat (220 ha), with approximately 350 hectares of grassland for cattle.



Source: Mofya-Mukuka, et al., "How Can the Zambian Government Improve the Targeting of the Farmer Input Support Program," 4. Based on a diagram by Nicholas Sitko, Michigan State University for the Agro-Enterprise Learning Alliance for Southern and Eastern Africa in 2010 and reprinted in "The State of Food and Agriculture Report: Innovations in Family Farming," FAO, (2014), 25.

ZAMBIAN AGRICULTURE BY THE NUMBERS



LAND/WATER DATA

743,000 SQ KM
total land area

15%
of arable land is cultivated

5%
of cultivated land is irrigated

POPULATION DATA

15 MILLION
total population

60% to 40%
ratio of rural to urban

4.4%
annual urbanization rate

87%
live on less than $2/day

Sources: "Farm Block Development Program", presentation by Julius Shawa, Zambia Ministry of Agriculture and Livestock, (2014); World Bank Poverty Head Count Ratio at $2/day (PPP) at 2005 International Prices, (2010); World Bank Data, "Total Population" and "Urban Population as % of Total Population," (2014); USAID, "Zambia Profile-Property Rights and Resource Governance," (2010); "UN Water Country Brief-Zambia," FAO, (June 2013).

AGRO-ECOLOGICAL REGIONS[8]

Zambia is divided into three Agro-Ecological Regions (AERs). Based on climate and soils, **AER 2A has the greatest agricultural potential**, as well as the best access to transportation, water and power infrastructures.

AER 1	AER 2 (A & B)	AER 3
17.3 m hectares	27.4 m hectares	30.6 m hectares
Less than 800 mm rainfall per year	800 mm to 1,000 mm rainfall per year	More than 1,000 mm rainfall per year
80–120 growing days	100–140 growing days	160+ growing days
Suitable for millet, sorghum, lentils, bananas, paprika, baby corn, small ruminants, cattle, dairy, aquaculture and poultry.	Suitable for maize, sorghum, cassava, millet, rice, groundnuts, cow peas, tobacco, sunflowers, irrigated wheat, soybeans, horticulture, aquaculture, cattle, dairy and poultry.	Suitable for cassava, maize, millet, sorghum, beans, groundnuts, rice, coffee, tea, pineapples, cattle, dairy, poultry, small ruminants and aquaculture.

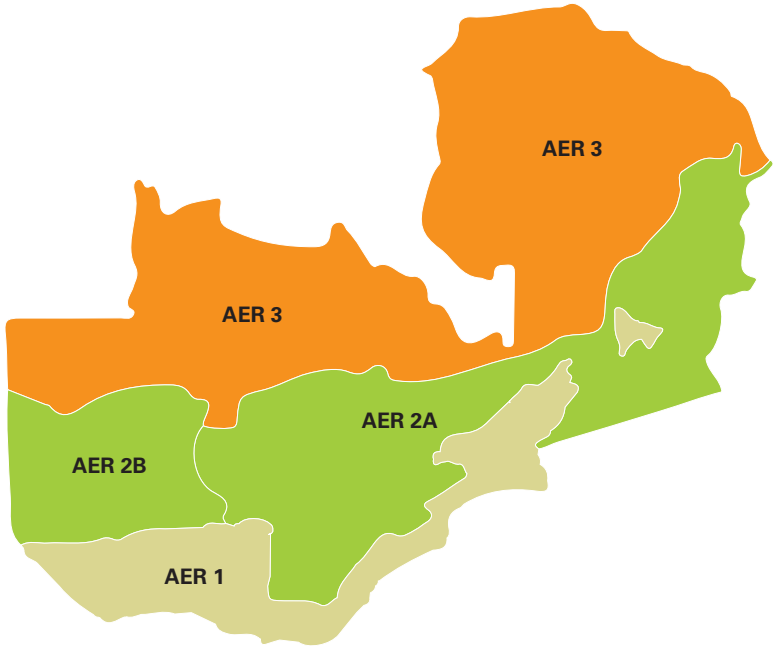
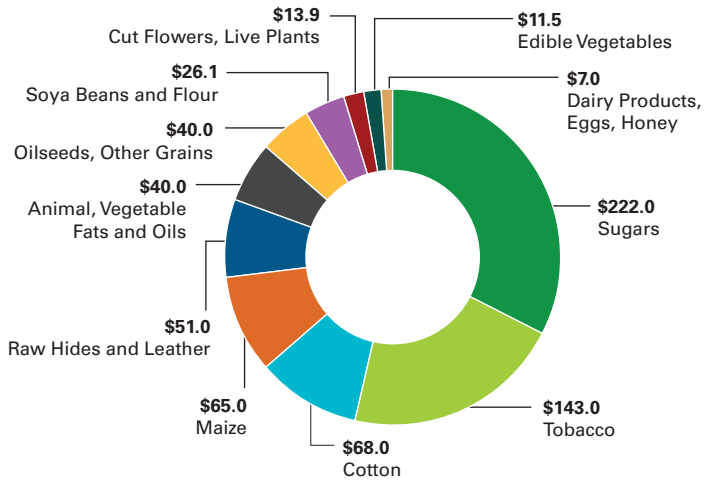


Figure 25: Value of Zambia's Agricultural Exports, 2014 ($ million)



Source: UN Comtrade Database (2014)

AGRICULTURAL EXPORTS

Zambian agricultural products can be found around the world. Cereals and cotton are exported regionally and globally. More than 60 varieties of cut roses are cultivated for markets in Europe and South Africa. Forty-seven percent of horticulture exports are bound for the United Kingdom — including asparagus, snap peas, beans, baby corn, broccoli, eggplant and onions. Malawi purchases half of the animal skins and finished leather goods produced in Zambia.

GLOBAL FOOD SECURITY INDEX SCORE[9]

The **Economist Intelligence Unit's Global Food Security Index (GFSI) sponsored by DuPont** uses tested indicators to evaluate food security performance in more than 100 countries. The GFSI data is used by policymakers, multi-lateral organizations, NGOs and civil society organizations to monitor country and regional progress towards food and nutrition security. Zambia's overall score is 32.9 out of 100, ranked 102 out of 109 countries. Zambia's GFSI score and ranking reflect several challenges in the high cost of food, as well as a lack of diversity in the diet. Governance is an area of strength for Zambia with solid scores for political stability as well as for having an agency to ensure food safety and a national nutrition strategy.

Affordability:	Availability:	Quality and Safety:
Score: 21.1	Score: 46.7	Score: 24.9
Rank: 105	Rank: 83	Rank: 105

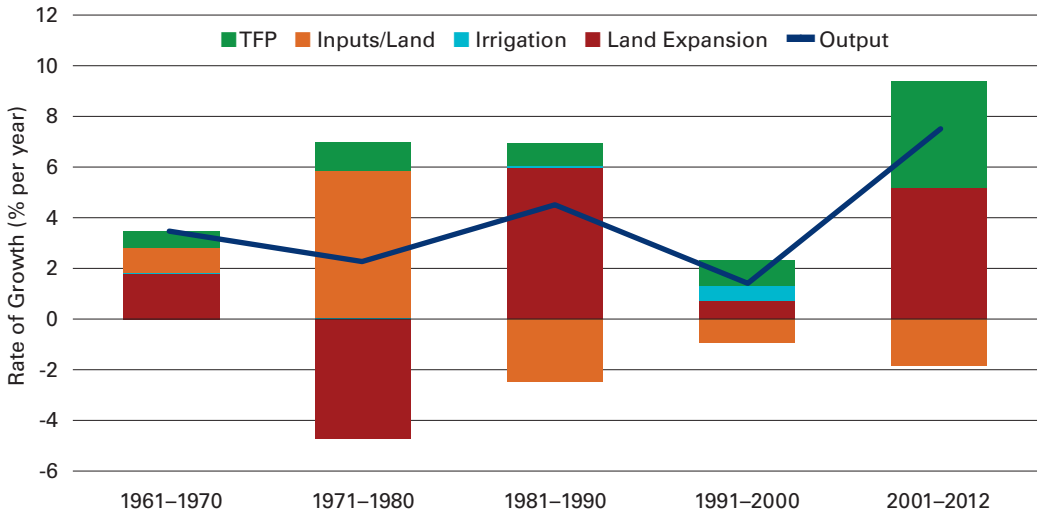
TFP IS ON THE RISE — WITH ROOM TO GROW

Zambia's strong growth in agricultural output over the last decade, averaging between 7 and 9 percent annually, has been prompted by a number of socio-economic and political transformations that occurred during the 1980s and 1990s. These include the transition to a market-based economy, an influx of experienced and well-capitalized farmers from South Africa and Zimbabwe, a growing class of medium-scale farmers with access to capital, increases in foreign direct investment in agriculture and a surge in the amount of land under cultivation. Total Factor Productivity has contributed appreciably to this increase in output since the turn of the century (Figure 26).

In the last few years, Zambian production of crops and livestock has grown extremely rapidly. For crops, land area devoted to maize and sugar cane has expanded, and yield has risen significantly for maize. For cattle, slaughter rates have risen from about 10 percent of the cattle herd to about 30 percent. This implies that the average age at slaughter has fallen from 10 years to 3 to 4 years. Feed use also rose very sharply, suggesting that more cattle were being finished in feed lots rather than on pasture. This indicates an increase in meat output, given the size of the cattle herd, and higher overall cattle productivity, even accounting for the rise of feed use.

Increasing TFP's contribution to Zambia's agricultural output will require public and private sector investments that improve the efficiency and sustainability of Zambia's producers. **There is an opportunity to raise productivity among the 1.33 million producers who presently account for just 31 percent of all agricultural output.** This will require an increase in, and refocusing of, public sector investments away from input subsidies and marketing supports towards research and development and extension services that deliver education and innovation for small-scale producers. These producers will also require more and better access to capital, secure land tenure, mechanization and improved seed and fertilizer. Investments in transportation, electricity and water infrastructures in rural areas are also needed to open up domestic and regional markets for farmers and help generate off-farm employment opportunities.

Figure 26: Sources of Growth in Zambian Agricultural Outputs, 1961–2012



Source: Economic Research Service (2015)

LAND EXPANSION

Over the last two decades, the Zambian government has put tens of thousands of hectares of uncultivated arable land into production. Land title is granted in the form of **leaseholds** obtained from government or customary authorities, or by purchasing previously titled land on the private market.[10] Government leaseholds vary in length from 14 years for emerging farmers to 99 years for large-scale domestic and foreign investors. Customary authorities (sometimes called "tribal" authorities) can also grant leaseholds, but most of the land under customary administration is held in common with the community. Customary authorities can give individuals the right to cultivate specific parcels of land, but most people living on customary land have no form of registered land title.

Zambia has some areas suitable for expanding agricultural production, but policies that promote greater productivity on existing cultivated land also need to be prioritized, along with an expansion of conservation farming in fragile and drought-prone regions. This will allow Zambia to meet demands for greater agricultural output while avoiding carbon release from land conversion and conserving habitat and biodiversity.

MAIZE PRODUCTIVITY

Zambia's strong TFP growth has also been stimulated by increased efficiencies in the use of inputs such as fertilizer, machinery and hybrid seed by small and medium-scale producers, as well as the adoption of data and precision agriculture by large-scale farmers.

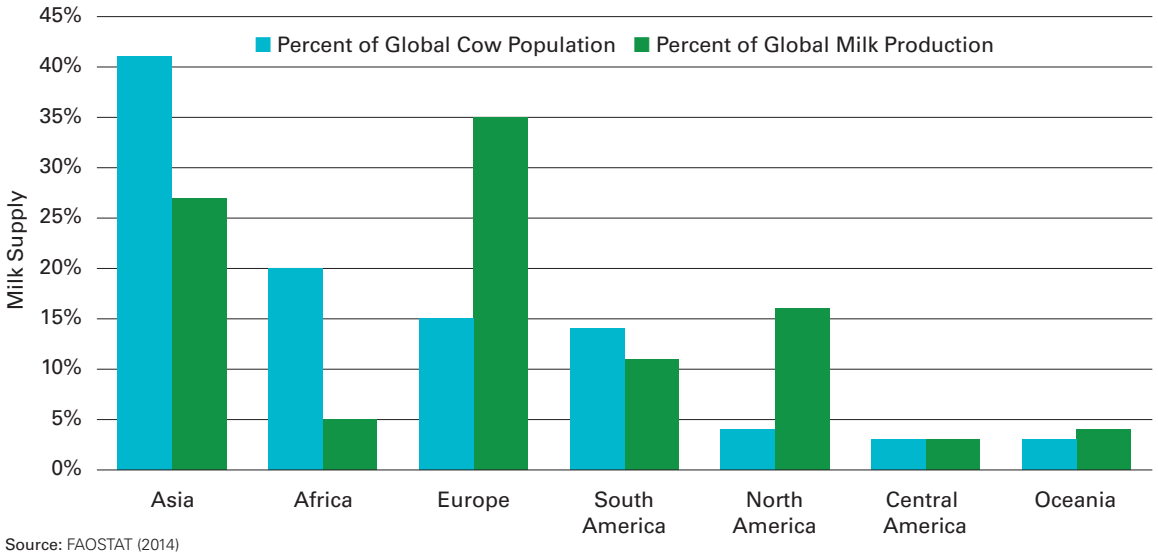
At the same time, land expansion has also contributed a large share of the total growth in agricultural output, particularly in the case of maize, Zambia's major cereal crop. From 2005/2006 to 2009/2010, maize production doubled from 1.4 million to 2.8 million metric tons.[11] **Efficiency of production contributed approximately 40 percent of the production increase — a success story**, given that almost all of the increase can be attributed to small and medium-scale producers who have less access to capital and inputs. At the same time, the land area cultivated for maize increased by 60 percent from 733,000 to 1.2 million hectares, making land expansion the primary driver of the increase in maize production.[12]

LIVESTOCK PRODUCTIVITY[13]

While maize calories make up more than 60 percent of the diet in Zambia, domestic demand for animal products is expected to grow. In 2013, Zambian farmers raised 38 million chickens, 4 million head of cattle, 2.74 million sheep and goats and 1 million pigs. Zambia is a net exporter of some animal products, such as raw hides and leather, but almost all animal protein products are consumed domestically, supplemented by imports to help meet demand. In 2012, Zambia imported 1,600 tons of chicken meat (value $1.7 million) while exporting only 33 tons (value $121,000). Zambia also imported 838 tons of cattle, boneless beef and veal and beef preparations (value $3 million), while exporting only 96 tons (value $327,000).

Low milk productivity is a challenge in Zambia, and throughout Africa which has 20 percent of the dairy cattle in the world, but produces only 5 percent of the global milk supply. (Figure 27) North America and Europe, on the other hand have only 19 percent of the dairy cattle and produce more than 50 percent of the milk supply. Improving the milk productivity per cow in Zambia will reduce greenhouse gas emissions and increase the availability of an important source of animal protein in a country where 45 percent of the population is malnourished.

Figure 27: Global Milk Supply and Cow Population



Source: FAOSTAT (2014)

VACCINATION PROGRAM INCREASES LIVESTOCK PRODUCTIVITY

Disease is the greatest threat to the Zambian livestock industry and can be particularly devastating to small and medium-scale producers, for whom livestock can account for up to 50 percent of their income. In 2005, the **International Fund for Agricultural Development (IFAD)**, the **UN Office for Project Services**, and the **Zambian Ministry of Agriculture and Livestock** launched the **Smallholder Livestock Investment Project (SLIP)** which provides vaccinations free-of-charge and raises awareness of the effectiveness of livestock vaccinations. For the program participants, vaccinations lowered the mortality rates of cattle from East Coast Fever (Bovine theileriosis) from 90 percent to less than 10 percent.

Vaccination education proved to be the most difficult, and yet the most important part of the project. Brendan Choobe, a community livestock worker, was successful in convincing his neighbors to vaccinate their herds, increasing the number of vaccinated cattle by more than 200 percent. Brendan's own herd has more than tripled in size to 75 head, thanks to vaccinations. In 2015 SLIP was expanded to include an additional 900,000 households.

Pictured above: A calf is tagged after having been vaccinated as part of the Smallholder Livestock Investment Project (SLIP), an IFAD-funded initiative in Zambia. The project is revitalizing the smallholder mixed-farming system that was devastated by cattle diseases in the 1990s. Photo source: ©IFAD/Siegfried Modola

ZAMBIA'S AGRICULTURAL VALUE CHAIN

Maize comprises 90 percent of Zambia's cereal production and 60 percent of the calories consumed in the country. The sequence of steps from maize producer to consumer demonstrates the opportunities that exist in Zambia's agricultural value chain (AVC) to increase productivity, reduce waste and loss, provide economic and social benefits and protect the environment through the production of maize and other agricultural products.

GHI's five strategic policy goals, introduced on pages 14–15, create the enabling policy environment that can allow Zambia's AVCs to **conserve** natural resources, **adapt** to climate change and consumer preferences and **improve** livelihoods, food security and nutrition.

FIVE STRATEGIC POLICY GOALS

Farmers and Producers

Zambia has a large and diverse group of agricultural producers, including large-scale farmers producing for export markets using advanced mechanization, inputs and irrigation, an emerging class of medium-scale farmers producing for domestic markets and small-scale and subsistence producers who may sell to local markets but are net food buyers. Farmers of all scales need technology and information to increase crop and animal output and reduce post-harvest losses while minimizing their impact on the environment. For small-scale producers, conservation farming can increase yields and help mitigate risks from climate change and weather shocks. A decade ago, Zambia created the **Farm Block Development Program**, opening the way for public-private sector partnerships that concentrate infrastructure and investments to create market and employment opportunities for large-scale agribusinesses and hundreds of medium-scale producers. Extending public goods such as transportation, electricity and water into isolated areas that are environmentally suitable for land expansion by small-scale producers will help increase their productivity and incomes.

Service Providers

Expanding access to productivity-enhancing and labor-saving inputs, such as fertilizer and hybrid maize seed, is critical to improving the productivity and sustainability of all Zambian producers. The government announced that its **Farmer Input Support Program (FISP)** is transitioning to an e-voucher system that will enable program participants to purchase fertilizer and seed in the private market instead of receiving them from the government. Farmers need more and better public sector agricultural extension and private sector advisory services in order to maximize the benefits of these advanced inputs. The **Zambian National Farmers Union (ZNFU)** promotes the use of conservation farming techniques among small-scale producers and also collaborates with agribusinesses to facilitate farmer education and financing. In 2015, ZNFU announced a new partnership with the European Union to construct and rebuild six agricultural service centers to give farmers centralized access to input suppliers and traders.

Aggregators

Some farmers have on-site storage facilities to maintain the quality and freshness of their products, but most need to store it off-site or sell it to an aggregator or trader who has access to storage. Post-harvest loss rates in Zambia are high. For maize, post-harvest losses averaged 16 percent per year from 2000 to 2010; the average annual value of the losses was $47 million.[14] The largest aggregator of maize is the Zambian government, which sets market prices and purchases maize from small and medium-scale farmers through the **Food Reserve Agency (FRA)**. As a result of recent bumper maize harvests, the FRA has exceeded its storage capacity, which has resulted in increases in maize loss. The FRA released some of its excess stores to the domestic and regional markets, which can reduce the amount of waste, but doing so can also reduce the farm-gate price that farmers receive from private traders.

Financial Services

Lack of access to affordable financing remains a stumbling block for farmers who want to make capital investments. Innovative financing and training programs are giving small and medium-scale farmers access to technologies such as small-frame tractors, trucks, harvesters and sprayers. Stabilizing the incomes of poor rural producers through social protection programs, such as cash grants, is another way of encouraging savings and investment in on-farm and off-farm enterprises. Extending mobile banking services will increase small-scale producers' participation in the formal banking system.

Risk Management

Climate change models predict that over the next 15 years, maize yields in southern Africa could fall by 30 percent due to temperature increases.[15] Individual farmers are managing risks posed by climate change and weather shocks with conservation farming techniques. Upwards of 100,000 Zambian farmers practice some form of conservation farming, more than any other country in sub-Saharan Africa. For maize, the prices set by the FRA are intended to protect small-scale farmers from price shocks and ensure that the government has enough maize to meet national consumption and industrial needs. But these market-distorting interventions can pose challenges. Private traders and large-scale producers are leaving the maize market and transitioning to soy or other crops. Establishing a national commodity market would make maize markets more predictable and profitable, and be a more effective way to manage risk.

Agro-Processors

Public-private partnerships with agribusiness are bringing storage and processing facilities for maize and cotton into rural areas. This reduces post-harvest losses, gives more farmers the opportunity to participate in the AVC and opens up opportunities for off-farm employment. Upgrading and extending the transportation, electricity and communications infrastructures that link producers, processors and retailers needs to be a top investment priority and represents an excellent opportunity for public-private partnership. Improving the reliability and affordability of Zambia's infrastructure systems will increase productivity and facilitate value chain development and trade.

Retailers

Maize products (particularly mealie meal) are staples for rural and urban consumers alike. In rural areas, food retail is comprised principally of local enterprises and informal markets. But rising incomes, urbanization and diversified diets have also led to the proliferation of South African-based supermarket chains such as SPAR and Shoprite. Integrating local producers into these high-end retail markets requires collaboration and commitment between the retailers who are looking for products that meet certain safety and quality standards and producers who need the appropriate inputs and training to meet their requirements.

Consumers

Maize is inexpensive, readily available and high in carbohydrates, but it lacks essential micronutrients, such as vitamin A. In Zambia, more than half of children under the age of 5 are vitamin A deficient, which can lead to loss of vision, impaired immune systems and other ailments. The International Maize and Wheat Improvement Center (**CIMMYT**) and **Purdue University** are part of an international effort to develop "Orange Maize," which is rich in vitamin A.[16] With support from the U.S. government's **Feed the Future** program, farmers in Zambia's Eastern Province are cultivating and consuming Orange Maize, which can provide up to 50 percent of the daily vitamin A requirement. To improve nutrition and producer incomes, Zambia must also incentivize the development of value chains and stimulate consumer demand for higher-value nutrient-rich foods, such as fruits and vegetables.

LAND AND WATER: THE ROOTS OF PRODUCTIVE AGRICULTURE

In 2006, the Zambian Government launched the **Farm Block Development Program** to "commercialize agricultural land and exploit its full potential in order to attain economic diversification and growth."[17] Farm blocks are outgrower arrangements centered on a "Core Venture" — an agro-processer or value-added agribusiness that provides a market and employment for more than 300 producers farming nearby plots that range from 25 to 10,000 hectares. In exchange for setting up the Core Venture, investors receive incentives such as low land rents, favorable income tax rates and exemptions from customs duty on agricultural machinery.[18] The government also develops the infrastructure for the farm block, including electrification, dams and access roads.[19]

The Farm Block Development Program has set aside 1.5 million hectares for agricultural production. In 2010–2011, the Zambian government invested $13 million in farm block development including roads, electrification and water infrastructures.[20] For the **Zambia Development Agency (ZDA)**, recruiting Core Venture investors from China is a top priority. The Zambian Ministry of Commerce, Trade and Industry estimates that there are 280 Chinese enterprises operating in Zambia with an estimated value of $5.3 billion, but these enterprises are focused largely in the mining and construction sectors.[21]

Some critics have characterized Zambia's farm blocks as "land grabs" in which foreign investors acquire land and utilize the labor of indigenous Zambian producers, driving up poverty and food insecurity. Through the application of advanced inputs and technologies, foreign and domestic investments have increased agricultural productivity, but some of these projects have created fewer local employment opportunities than anticipated.[22] This has fueled promises from government officials to scrutinize future investment proposals more closely.[23]

THE MKUSHI DISTRICT

The most active and productive of Zambia's farm blocks — the Mkushi District — was created during Zambia's colonial period. In the 1950s, the North Rhodesian government set aside 71,000 hectares of land north of Lusaka for European settlement and cultivation.[30] For decades, the project struggled to take hold, but today Mkushi is a thriving agricultural region. Mkushi farmers are the country's largest producers of wheat and soybeans, as well as the sixth largest producers of maize.[31] Farmers of all scales have settled in Mkushi: medium and large-scale producers and processors from Zambia, South Africa and Zimbabwe, as well as small-scale and subsistence farmers who rely on the larger operations as a market and source of employment. Electrification of the district in 2002 made center pivot irrigation financially viable and together with an influx of large-scale mechanization transformed Mkushi into Zambia's agricultural heartland.[32]

Photo Source: Jessica Chu, School of Oriental and African Studies, University of London

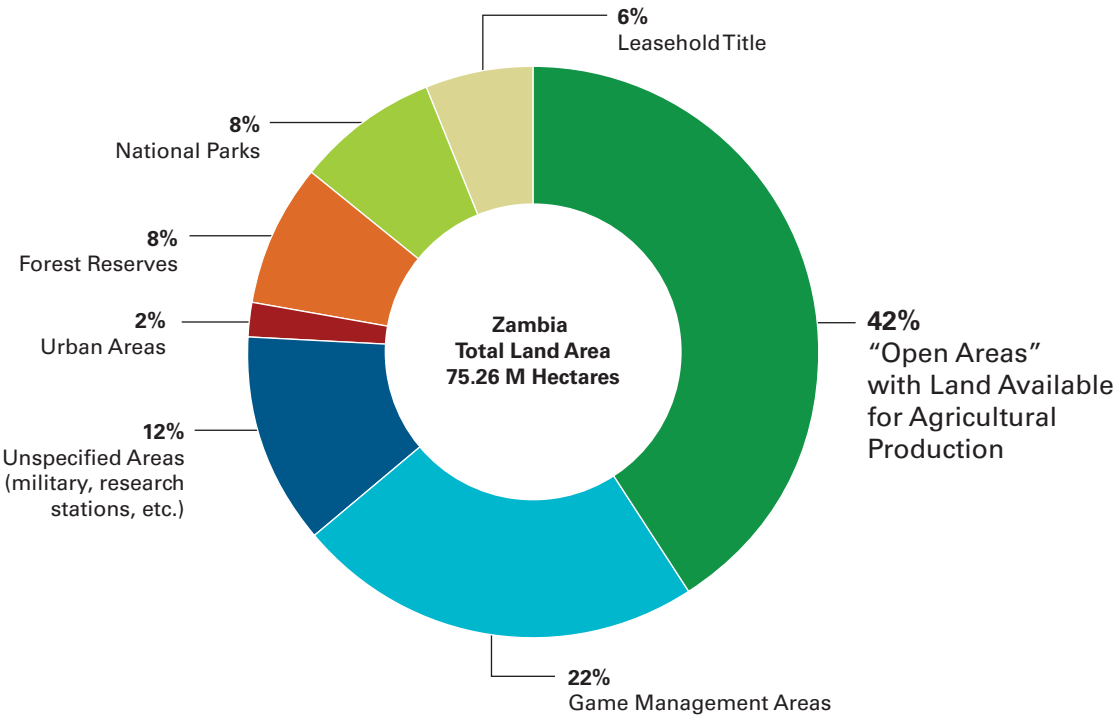
Interviews with farmers in affected communities capture the complex perspectives of local Zambians with regard to foreign investment. Farmers in the Mkushi District indicated a willingness to take a wait-and-see approach, explaining that they see the new arrivals as the latest "wave" of foreign investors and expatriate farmers who have come to Zambia over the last century.[24] On the other hand, a 2015 study by the **Zambia Land Alliance (ZLA)** of investments in the Mumbwa District revealed apprehension and opposition, particularly among women who often lack secure land tenure, to the decision to allow foreign investment.[25]

SECURING ACCESS AND TENURE FOR SMALLHOLDERS

For the 96 percent of Zambian producers who cultivate less than 5 hectares, farm blocks are largely out of reach: the minimum farm size of 10 hectares, application fees and credit requirements are prohibitive.[26] Increasing access to secure land title for small-scale producers needs to be a priority, particularly for women who are more likely than men to invest in productivity-enhancing technologies.[27] In order to secure land leaseholds, most subsistence and small-scale farmers must negotiate with local chiefs or rely on private land markets. For women, obtaining leaseholds is further complicated by the patriarchal traditions in customary areas. As a result, women are more likely to secure leaseholds by purchasing previously-titled land on the private market, whereas men are more successful in obtaining leaseholds directly from local chiefs.[28] In lieu of a formal leasehold, men and women can receive permission from customary authorities to cultivate a specific plot of land, but this permission does not secure their tenure.

Additionally, the majority of the land that is available to smaller producers for agricultural expansion has very little access to roads, electricity or irrigation infrastructures, which hampers their productivity and access to potential markets. Rural areas that have access to productive inputs and markets are more densely populated, with as many as 500 people per square kilometer.[29] Extending public goods such as transportation, electricity and water into areas suited for smallholder expansion will increase the yields, productivity and incomes of Zambia's small-scale farmers.

Figure 28: Land Area Available for Agricultural Production



Source: Adapted from Sitko and Jayne, "The Rising Class of Emergent Farmers," (2012) and S. Metcalfe, "Landscape Conservation and Land Tenure in Zambia," (2005)

Forty-two percent of Zambia's land is classified as "Open Area" and is potentially available for agricultural production. Expanding production in these regions needs to be carefully managed to avoid and/or minimize the potential social, economic and environmental impacts. For example, not all of the land in Open Areas is arable and some of it is too environmentally sensitive to be put into production. Additionally, some Open Areas are occupied; expanding production could necessitate resettling communities who already inhabit and cultivate the land.

Expanding production in Open Areas is further complicated by a complex land management system that gives both the government and customary authorities a role in determining how the land is used and who has the right to use it. The challenge of navigating this dual governance structure can deter large-scale producers from expanding their operations and hamper small-scale producers' efforts to secure the land tenure they need to grow their on and off-farm enterprises.

Kafue Fisheries, located on the Kafue River, integrates aquaculture with pig and game farming. They produce approximately 1,300 tons of fish per year for markets in Lusaka. Photo source: Damian Newmarch, Kafue Fisheries Ltd. and AGRICO Pty. Ltd.

MEETING ZAMBIA'S DEMAND FOR FISH THROUGH SUSTAINABLE AQUACULTURE[33]

Fish are the most commonly consumed source of animal protein by Zambians, particularly in rural areas. Thirty-seven percent of the animal protein consumed in poor, rural households comes from fish, almost double the amount that comes from meat (24 percent) or poultry (22 percent). But Zambia has a "fish deficit": more than one-third of the 156,000 metric tons of fish consumed in Zambia in 2013 had to be imported. At the same time, only 20 percent of fish production in Zambia is produced using sustainable aquaculture techniques (farmed in floating cages or in purpose-built ponds), while 80 percent of fish is "captured" in lakes, rivers and reservoirs. Increasing sustainable aquaculture production can help Zambia meet its "fish deficit" without putting further pressure on its already stressed water resources and declining fish populations. Partnerships with knowledgeable institutions and experienced aquaculture farmers can help Zambia sustainably meet its growing demand for fish and ensure the availability of an affordable, protein-rich food.

LOTS OF WATER...BUT NOT EVERYWHERE

Zambia lies at the heart of the Zambezi and Congo River Basins, has four major lakes, as many as 1,500 individual dams and a mean annual rainfall of 1,020 millimeters.[34] Between 400,000 and 500,000 hectares of land are considered irrigable, but only 150,000 hectares are equipped for irrigation, just 5 percent of the total cultivated land area.[35] The main irrigated crops are sugar cane, wheat and rice. Forty percent of irrigated land is cultivated by large-scale farmers, including wheat producers in the Mkushi District and the Nakambala Sugar Estate which cultivates more than 11,000 irrigated hectares.

Center-pivot irrigation systems have made Zambia's large-scale farms among the most productive in Africa. Medium-scale producers are more likely to use drip or gravity systems such as stream diversion and furrows; treadle pumps and water harvesting techniques have expanded irrigation options for small-scale and subsistence producers. Despite the potential for irrigation to increase productivity and livelihoods, the Zambian government allocated, on average, only 11.6 percent ($1.04 million) of its annual water-related expenditures for agricultural projects (2006–2010).[36]

INVESTMENTS IN DRINKING WATER AND SANITATION

From 2006 to 2010, Zambia spent an average of $5.13 million per year on developing the water supply and sanitation systems in urban and rural areas.[37] The investment has paid off: the number of people with access to improved drinking water has more than doubled. Significant gaps remain; only 46 percent of the rural population and 87 percent of the urban population have access to safe drinking water.

A young woman collects water at a micro irrigation project by the International Fund for Agricultural Development (IFAD). Photo source: ©IFAD/Siegfried Modola

CONSERVING WATER AND SOIL

Climate change models for southern Africa predict that over the next 15 years, maize yields could fall by 30 percent due to temperature increases.[38] A growing number of subsistence and small-scale farmers are adapting to changing weather patterns using **conservation farming** techniques that retain moisture in the soil by reducing tillage, retaining crop residues and rotating cereal with legume crops. The Zambian government and the **Zambian National Farmers Union** are actively promoting and educating farmers about the benefits of conservation farming. As a result, **Zambia boasts more conservation farmers than any other country in sub-Saharan Africa**. While estimates vary, between 120,000 and 170,000 farmers are using some form of conservation farming either full time or to mitigate risk during drought seasons.[39]

A review of conservation farming outcomes in Zambia by FAO identifies a **correlation between conservation farming techniques, improvements in soil moisture and increasing yields for smallholders** in the drier areas of Zambia.[40] There is concern that conservation farming techniques put a larger labor burden on women, as the reduction in tillage necessitates more weeding — a task traditionally performed by women. The profitability of conservation farming is another potential issue, since it necessitates hiring additional labor to plant and harvest crops. Nonetheless, the FAO report encourages continued research into best practices for conservation farming and support services for farmers in Zambia.

INVESTING IN PRODUCTIVITY

Zambian farmers of all scales are investing in productive assets such as mechanization, precision agriculture technologies, fertilizer and hybrid seeds. Household survey data show that between 2004 and 2008 small and medium-scale producers increased their ownership of hand-driven tractors (289 to 719), sprayers (115,512 to 122,810), shellers (1,278 to 1,671) and hammer mills (9,954 to 14,480).[41] Records of mechanization purchases by Zambia's largest farms and agribusinesses suggest that large-scale farmers were also investing in fixed capital assets during this period.[42]

Nonetheless, a lack of access to financing remains a significant impediment to investment for most of Zambia's small-scale and subsistence farmers. The World Bank reports that Zambia's overall financial inclusion indicators are lower than those for other lower-middle-income countries: 19 percent of adults have an account with a financial institution, 32 percent have some form of formal or informal savings and 6 percent report having borrowed from a financial institution in the past year.[43] Growth in mobile financial services has been slow — 72 percent of Zambians have a mobile telephone, but only 6 percent use mobile banking. In addition to lack of access, farmers report that a burdensome application process and the short terms of the loans make it difficult to obtain credit.

FINANCING MECHANIZATION

Farmers and agricultural producers rely on mechanization and precision agriculture systems to increase the productivity, profitability and sustainability of their operations. To acquire these technologies, producers need access to affordable and appropriate financing packages.

Land leaseholds and well-established financial histories provide large-scale farmers with the security they need to obtain financing for advanced, data-driven machinery

Raj Patel has been farming in Kabwe, Zambia, for 32 years. He produces a diverse array of products, including seed maize, seed soya, wheat, tobacco and mangos, as well as chicken and sheep. Photo source: Amadeus International and AGRICO Pty. Ltd.

for planting, spraying, harvesting and milling. Still, traditional banks are not always familiar with the financial cycles and risks of agriculture, which do not mesh easily with standard loan repayment schemes. Collaboration between mechanization companies and banks, such as **John Deere** and **Standard Bank**, has led to the development of financial products that give farmers the flexibility they need in order to invest in their operations.

Small and medium-scale farmers, who are less likely to have land tenure or a financial history, are obtaining access to mechanization technologies thanks to a number of innovative financing tools and programs. **John Deere Financial, AFGRI**, a leading supplier of agricultural equipment in Africa, and **Zanaco Bank** are partnering with the **Zambian National Farmers Union (ZNFU)** to identify and train farmers, or groups of farmers, to become mechanization contractors. ZNFU and John Deere train the farmers to use and maintain the equipment, which will serve as the collateral for their loan. Just as importantly, the contractors learn business and farm management skills which will help them be successful borrowers. As a result, an entire community of farmers can affordably access the mechanization technology they need to increase their agricultural output and generate additional income.

HEALTHY SOILS

The United Nations **2015 International Year of Soils** has drawn renewed attention to the importance of **balanced crop nutrition** to maximizing yields today and the sustainability of crop production tomorrow. Properly balanced crop nutrition allows plants to use nutrients and water more efficiently, resulting in higher yields on the same amount of land. This frees up land for other productive uses, including habitat and wildlife conservation. Identifying the amount and type of nutrients needed by specific soils and matching them with the needs of a particular crop is essential for sustainable and resilient intensive crop production. Maintaining this delicate balance involves regular soil testing and careful monitoring.

Crop fertilization is one of the most important productivity-enhancing practices, yet many of Zambia's small-scale and subsistence farmers are struggling to access and/or afford fertilizers. In 2010, Zambian farmers paid $1,400 per metric ton for nitrogen-based fertilizers — the fifth highest rate in Africa.[44] Those who do use fertilizer often lack the knowledge to identify and maintain the right mix of nutrients for their soils and crops.

Priced out of private fertilizer markets, one potential source of fertilizer for small and medium-scale farmers is the **Farmer Input Support Program (FISP)**. For FISP recipients, the Zambian government purchases and distributes fertilizer (and hybrid seed), subsidizing as much as 79 percent of the cost (2012/2013). Both the quantity of fertilizer distributed and the number of recipients has skyrocketed. In 2002/2003, 48 metric tons were distributed to roughly 100,000 beneficiaries; in 2012/2013 nearly 180,000 metric tons were distributed

to 900,000 beneficiaries.[45] Despite this increased investment, the reach of FISP is limited. Approximately 10 percent of Zambia's 1.4 million farmers cultivating less than 20 hectares receive fertilizer and seed through FISP.

In 2015, the Zambian government announced that it will begin phasing out FISP and transitioning to an e-voucher system that will enable beneficiaries to purchase fertilizer and seeds from the private market.[46] Farmers will receive a "credit card" loaded with ~$160 (50 percent is contributed by the beneficiary) to be used for input purchases. The goal is to improve input delivery, provide flexibility and reduce the market-distorting impacts of government fertilizer and hybrid seed purchases. Still, many rural agro-dealers do not have the capacity to process credit card payments, making it difficult for them to supply beneficiaries in more isolated regions. A pilot program targeting 214,000 recipients in 13 districts has been announced for the 2015/2016 growing season.

Replacing FISP with a more cost-efficient input support system frees up resources for high-return investments such as research and development, agricultural extension and education, or transportation and irrigation infrastructures.

THE NEED FOR SEEDS

FISP also distributes hybrid maize seed to its beneficiaries. Small-scale farmers use a combination of hybrid and local maize seed, but the hybrid seed accounts for 90 percent of their production. This is consistent with studies in Kenya that have shown hybrid maize increases yields by 7 to 9 percent over open pollinated varieties (OPVs) and by 67 to 76 percent over local landraces. Zambian producers using hybrid seeds are 15 percent more likely to sell maize and increase the quantities sold by 64 percent.[47] In addition to increasing yields and sales, hybrid seeds are a scale-neutral technology that reduces risk, stimulates off-farm markets and plays a critical role in helping farmers adapt to climate change and weather shocks.

PANNAR SEED, an affiliate of DuPont Pioneer, operates test fields and provides advisory services for Zambia's small-scale and emerging producers. Janet Mandela (above) is part of a farmer cooperative that is cultivating 3.2 tons of maize per hectare with hybrid seed. Photo source: Barbra Muzata, DuPont Pioneer

Investments are needed in the research and development of plant breeding and seed systems, particularly varieties that improve yields and reduce risk for smallholders. Expanding agricultural extension and advisory services will help farmers maximize the benefits of hybrid seed technology.

While Zambia does not currently allow genetically modified crops, the government has signed the **Seed Trade Harmonization Act** for the **Southern African Development Community (SADC)**. The Act will create a consistent regulatory framework for seed trade in southern Africa, giving Zambian farmers access to a wider variety of hybrid seeds and stimulating investment in the development of hybrid seed varieties that are tailored to meet the needs of farmers in the region.[48]

DROUGHT TOLERANT MAIZE SEED FOR AFRICA

Maize is the primary source of calories for more than 300 million Africans, but frequent droughts and rising temperatures are threatening this vital food source, as well as the livelihoods of farmers across the region. The **Water Efficient Maize for Africa (WEMA)** partnership* is developing and delivering hybrid maize seed that uses water more efficiently and resists insects and pests to small-scale farmers who rely on maize for food and income. As a leading WEMA partner, **Monsanto** shared 600 elite parental lines of maize seed, along with technical plant breeding know-how and biotech drought-tolerant and insect protection traits. Monsanto also leveraged the expertise of local research partners to develop locally adapted hybrid maize.

The first harvest of WEMA white hybrid maize seed took place in Kenya in February 2014. Farmers experienced improved grain yield under both optimal and drought stress conditions, harvesting 4.5 tons per hectare compared to 1.8 tons per hectare harvested in the first farmer-managed demonstration trials.

WEMA is now delivering conventional seeds under the brand DroughtTEGO™ with 40 new hybrids approved for commercial release and more in the development pipeline. Seed licenses are available, royalty-free, to all seed companies, and more than 20 seed companies have made these seeds commercially available to African farmers. **The WEMA project is the largest tropical white maize breeding program in sub-Saharan Africa**, and DroughtTEGO™ branded hybrids are expected to enable farmers to harvest 20–35 percent more grain under moderate drought conditions compared to the seed they have historically planted.

**Water Efficient Maize in Africa (WEMA) is led by the African Agricultural Technology Foundation (AATF), and funded by the Bill and Melinda Gates Foundation, the Howard G. Buffett Foundation and the United States Agency for International Development (USAID). Key WEMA partners include the National Agricultural Research Institutes in Kenya, Mozambique, South Africa, Tanzania and Uganda, the International Maize and Wheat Improvement Center (CIMMYT) and Monsanto. DroughtTEGO™ is a registered trademark of AATF.*

KNOWLEDGE IS KEY

To maximize the productive potential of investments in land, water, seeds, fertilizers, mechanization and conservation, farmers need to know how to integrate these inputs in a way that meets the specific needs of their farms.

In 2015, the **Modernizing Extension and Advisory Services (MEAS)** initiative conducted a review of Zambia's Extension and Advisory System (EAS) in the Eastern Province, the focus area for the U.S. government's **Feed the Future** programs. The MEAS survey revealed that the public extension system as a whole is perceived to be inefficient and ineffective due to inadequate funding, multiple vacancies in extension officer positions, poor training and a lack of experience of the extension agents.[49]

Public sector investments in agricultural research and development in Zambia are anemic. Since 1981, government R&D spending, as a portion of agricultural GDP, has dropped from 2.35 percent to .29 percent, which translates to a decrease of spending per agricultural worker from $18.38 to $2.77.[50] By one estimate, there are currently two full-time equivalent agricultural researchers for every 100,000 Zambian farmers — the ratio in South Africa, by contrast, is 40 researchers per 100,000 farmers.[51]

The MEAS report recommended that EAS be repositioned to work more effectively with private sector research and extension services, which is where some of the most exciting activity is now happening. In August 2015, the Zambian National Farmers Union announced a $16 million partnership with the European Union ($14 million from the EU and $2 million from the ZNFU) to construct four new agricultural service centers and refurbish two others over the next four years.[52] These centers will be operated by agribusinesses, selected on a competitive basis, and will serve as one-stop shops for farmers to access inputs, advisory services and market information.

HORTICULTURE INNOVATION LAB TRAINS FARMERS TO SUCCEED FROM SEED-TO-SALE

Small-scale farmers in the Livingstone area are providing high-end hotels and major supermarkets with fresh produce thanks to the training they received through the **Horticulture Innovation Lab**, a joint project of **Rutgers, The State University of New Jersey, Purdue University, Stellenbosch University** and **Agribusiness in Sustainable Natural African Plant Products (ASNAPP)**.

In the Kazuni community, nearly 2 million seedlings for a variety of fruits and vegetables have been produced and sold as a result of training provided by the HORT Innovation Lab. Photo source: Paul Marcotte, Horticulture Innovation Lab Evaluator

The advisory services provided by the HORT Innovation Lab covered the entire horticultural value chain, from seedling production to post-harvest handling and commercialization. One of the keys to the project's success was the farmers' ability to access and reproduce high-quality germ plasm. In the village of Kazuni, community members received training in the construction and use of high tunnels for seedling production. By 2014, more than 2 million seedlings had been produced, including red and yellow peppers, broccoli, cauliflower, tomato, eggplants, melons, spinach and cabbage.

Private sector partners in the HORT Innovation Lab helped develop markets for the communities' produce. More than 100 metric tons of vegetables valued at $170,000 have been sold to SPAR and Shoprite supermarkets, as well as luxury hotels and lodges in and around Livingstone, a major tourist destination near Victoria Falls.

The final project evaluation reported that the HORT Innovation Lab has increased food security and incomes for the participants — 59 percent of whom are women. The income generated is being used for medical treatment, school fees and to build or expand homes. Three years after the completion of the project, the communities' horticulture businesses continue to thrive, with new orders for seedlings and produce coming in from as far away as Nairobi.

SOCIAL PROTECTION AND PRODUCTIVITY

For subsistence and small-scale producers, income instability is one of the greatest obstacles to increasing the productivity and profitability of their agricultural enterprises. Farmers cultivating less than 5 hectares of land rely on wage labor, such as working on larger farms or in processing facilities, for their main source of income. Agricultural wage labor is seasonal, which means that men and women are investing less time and energy in their own farms during critical planting and harvest periods. As a result, many rural Zambians are stuck in a cycle of "coping" — doing what they need to do to get by. This makes it difficult for them to increase the productivity of their own operations, accumulate savings for future investments or acquire knowledge and skills to work in a value-added agricultural business or non-agricultural trade.

The Zambian government's primary tools for addressing poverty among rural producers are its **Poverty Reduction Programs**: the **Farmer Input Support Program (FISP)** which provides subsidies for fertilizer and hybrid seeds and the **Food Reserve Agency (FRA)** which purchases maize from small-scale and emerging farmers. These programs take up 58 percent of the agricultural budget, but their limited scope and scale restricts their effectiveness as poverty-reducing, productivity-enhancing interventions.

Social protection programs, such as cash grants, provide the poorest rural residents with income stability and food security, while also reducing their reliance on agricultural wage labor and freeing them up to invest time and resources in their own farms, to develop off-farm enterprises or to pursue training for non-agricultural employment. In 2010, the Zambian Ministry of Community Development for Mother and Child Health (MCDMCH) piloted a **Child Grant Program (CGP)** in three provinces, where the program gave households with children under the age of five a total cash grant of $12 per month.[53] Payments were made monthly and without condition. Participants spent the additional money on food (76 percent), health/hygiene (7 percent), clothing (6 percent) and transportation/communications (6 percent). The program not only reduced the severity of poverty, it changed the participants' perception of their own food and income security: the number of households that reported being better off than they had been 12 months earlier increased by 45 percent.

The Child Grant Program, a pilot project in the Eastern Province of Zambia, provided families who have children under the age of 5 with a monthly grant of $12 which they used to purchase items such as food, healthcare and clothing. The grants helped stabilize family incomes, enabling parents to invest more time and resources in developing their farms and off-farm enterprises.

Perhaps most encouraging was the **increased investment in productivity-enhancing and labor-saving inputs, and the increases in agricultural output** by CGP beneficiaries.[54] The share of household expenditure spent on seeds, fertilizer and hired labor increased by 18 percent — with a 22 percent increase in input spending by the smallest households. The value of the overall harvest increased by 50 percent, on average, with most of the additional production being sold. CGP households increased both their ownership of livestock (21 percent) as well as the diversity of their livestock.

Finally, the income stability of the cash grants enabled participants, particularly women, to reduce their wage labor hours and develop their own enterprises. The percentage of households that operated off-farm businesses, increased by 17 percent.[55] The CPG grants also had a significant multiplier effect: each kwacha transferred to a recipient generated 1.79 kwacha in the local economy.

In order to move people from "protection to productivity," **social programs must be accompanied by investments and partnerships that improve producers' access to:**

- **secure land tenure**
- **transportation, electricity and irrigation infrastructures and**
- **agricultural knowledge and innovations developed and disseminated by a robust research and extension system.**

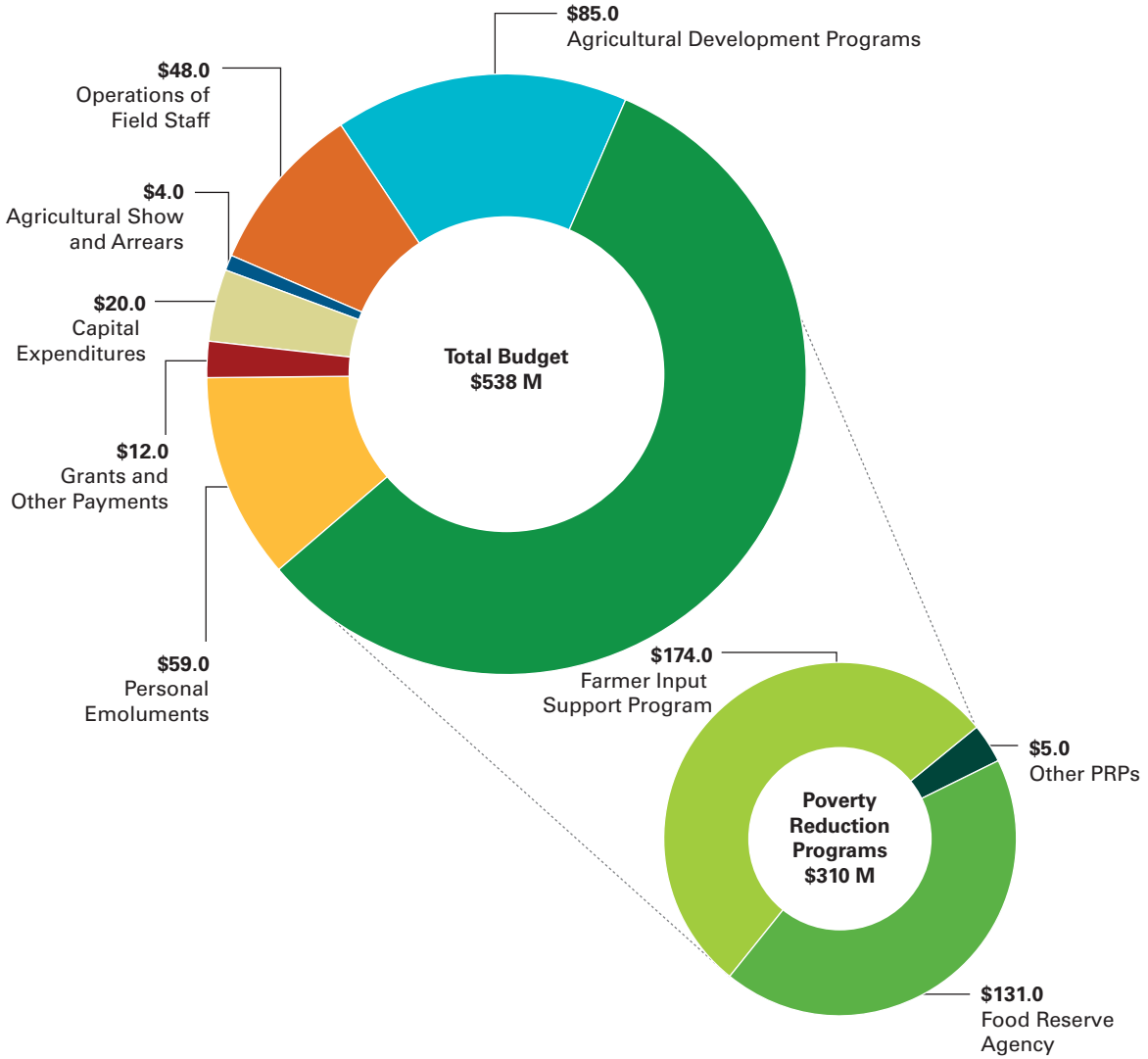
SHIFTING INVESTMENT PRIORITIES

Of the $538 million budgeted by the government for agriculture programs in 2015, 58 percent is slated for "Poverty Reduction Programs" including $174 million for the Farmer Input Support Program (FISP), which provides subsidies for fertilizer and hybrid seeds, and $131 million for Food Reserve Agency (FRA) purchases of maize from small and medium-scale farmers.[56] Meanwhile high-return investments are underfunded, including agricultural research and development, extension and advisory services and transportation, electricity and irrigation infrastructures.

In order to maximize limited resources, Zambian policymakers ought to consider shifting "poverty-reduction" dollars towards social grant programs, such as the Child Grant Program, that have a proven track record of both reducing poverty and increasing productivity among the poorest and most vulnerable rural producers — particularly women. By refocusing agricultural spending on investments with the greatest rate of return — R&D, infrastructure, irrigation and education — Zambia will be able to sustainability increase its agricultural output through TFP growth and realize its potential as a regional breadbasket.

Photo source: ©IFAD/Siegfried Modola

Figure 29: 2015 Budget for Ministry of Agriculture and Livestock ($US million, converted)



Source: 2015 Zambia Agricultural Budget Analysis, Indaba Agricultural Policy Research Institute (2014)

Fifty-eight percent of the 2015 Ministry of Agriculture and Livestock budget has been allocated to input subsidies and marketing support programs. Shifting funds to high-return investments, such as agricultural research and extension, will provide farmers with the skills they need to make their enterprises more productive and sustainable.

EXPANDING MARKETS FOR MAIZE, AND MORE

In Zambia, maize comprises 90 percent of the cereal outputs and 60 percent of the calories consumed. Over the next decade, domestic demand will continue to be the largest driver of maize markets, fueled by increases in population, incomes and demand for animal protein. Domestic feed demand alone is expected to increase 75 percent by 2023.[57] Research compiled by several regional policy institutes indicates that Zambia will continue to produce annual surpluses of maize, while its neighbors will have small surpluses or maize-deficits.[58]

In order to take advantage of this market opportunity, Zambia will need to make investments and market-reforms in its maize pricing system, transportation and power infrastructures. Reducing days-to-export by streamlining application processes and border crossing procedures will make Zambia a more efficient and desirable trading partner.

Eighty percent of Zambia's 1.4 million farmers produce maize, yet only 27 percent of rural households are net sellers of maize (2008).[59] The **Food Reserve Agency (FRA)** is the largest single purchaser of maize, particularly from small-scale farmers. It was created in 1996 as part of Zambia's market liberalization process to establish a strategic food reserve and stabilize market prices.[60] In 2005, the FRA took responsibility for maize crop marketing and price setting.

The FRA announces its buy price and targeted purchase amount in the late spring; maize is then collected by the government from July to October. (The FRA announced plans to purchase 500,000 tons of maize in the 2015/2016 marketing season.[61]) Farmers are to be paid within 10 days, but long payment delays are typical. At the end of 2014, only 30 percent of farmers had been paid by the government for their maize.[62] For small-scale producers, the uncertainty of the payment system complicates their ability to purchase inputs for the coming growing season, perpetuating a cycle of underinvestment and low productivity.

Erita Syamakaba tends to her cornfield near the town of Livingstone in southern Zambia. She and other members of her community make a steady income from farming by selling the crops to some of the best hotels in Livingstone. Photo source: ©IFAD/Siegfried Modola

While not all farmers receive the FRA premium price for their maize, Zambian maize is consistently the most expensive in the region, which makes it difficult to compete with less expensive maize from South Africa.[63] In addition to buying maize, the FRA occasionally sells part of its reserve to domestic industrial millers and processors at a below market price in order to reduce unwanted stocks and keep mealie meal, a Zambian food staple, affordable for urban consumers. This kind of inconsistent intervention in the maize markets by the FRA has proven to be a disincentive for private traders, as well as large-scale producers who are increasingly moving out of maize production.[64] In order to maximize market opportunities, particularly for small-scale farmers, market-enhancing reforms of FRA's structure and operations will be essential, including reducing the amount of maize purchased for the FRA and managing risk through commodity markets rather than stockpiles of maize.[65]

Figure 30: Maize Surplus and Deficit Countries in Southern Africa

Source: Adapted from "Bumper Harvests a Cure or a Blessing for Zambia", Chapato, et al, pg. 3. Based on data from the Southern Africa Development Community (SADC), 2014.

Zambia will have 877,000 metric tons of maize available for export in the 2015/2016 marketing season. A sharp reduction of maize output in South Africa in 2014/2015 could increase demand for Zambian maize in the region, particularly from the Democratic Republic of the Congo, Zimbabwe and Mozambique.

Hydro Electric Dam on Lake Kariba supplies electricity to the Copperbelt mining region of Zambia.

RELIABLE AND AFFORDABLE INFRASTRUCTURE

In order to maximize the market opportunities for maize, as well as other agricultural products such as soy, cotton, and livestock, it is critically important to invest in the expansion and improvement of the transportation, power, water and telecommunications infrastructures.

Zambia has invested heavily in developing its **hydro-electric power system** and has been, at times, a net exporter of electricity. But the power grid has been pushed beyond its limits by an aging system, lower water levels from a series of droughts and skyrocketing demand — particularly from the mining industry. Today, the country has a 600 mega-watt deficit and is unable to make up the difference by importing power from regional markets.[66] Regular and sustained power cuts decrease agricultural output and productivity because data and precision agriculture technologies require a reliable power source to maximize their productivity-enhancing

A group of farmers gather potatoes and load the truck for sale in Zambia and Malawi.

benefits. Farmers and mechanization suppliers are now looking at alternate energy sources, such as solar, as a way to stabilize power availability in large-scale operations.

Mobile phone access in Zambia has grown exponentially in the last five years. More than 70 percent of Zambians have access to mobile technology and the impact on the productivity of small-scale farmers is substantial. A survey of rural households found that small-scale maize producers who had access to market information through mobile phones increased their conditional and unconditional sales of maize by 81 percent and 76 percent respectively.[67] As has been previously noted, the mobile banking system is underdeveloped and its improvement is a critical component of expanding financing to rural producers.

As a land-locked country, Zambia is **heavily reliant on roads** for domestic markets and regional trade. Roads enable producers to access the value chain physically by facilitating the movement of their product to markets, and financially by enabling more private traders to access rural areas.[68] In 2009, the UN Conference on Trade and Development (UNCTAD) estimated that 70 percent of Zambia's trade volume traverses its 40,000 kilometer road network, of which only 7,200 kilometers are paved.[69] In 2012, the **Link Zambia 8000** project was launched with the goal of building and improving 8,000 kilometers of roads, with a particular focus on feeder roads that connect rural areas to mainline roads. In January 2015, the government reported that 2,500 kilometers of road had been paved or improved.[70]

FOR PRODUCERS, TIME IS MONEY

Access to transportation infrastructures is important, but the affordability of using the infrastructure also affects producers' profitability. In Africa, rural producers pay 45 percent of the total transport cost during the first 28 percent of the distance to the market.[71] Even with improved roads, the expenses incurred by multiple road blocks, bribes and long wait times at the border take a bite out of the price producers receive for their goods. The World Bank reported that a truck traveling a single 90 kilometer stretch of road into Nairobi, encountered 19 roadblocks, adding more than 3 hours to the travel time.[72]

Improving border crossing times will increase the competitiveness of Zambian agricultural producers by decreasing the cost of inputs such as fertilizer and machinery and by reducing the amount of product that goes to waste due to a lack of cold storage. **USAID Trade Hub for Southern Africa** worked with the Zambian and Tanzanian governments to establish a Joint Border Committee to improve the crossing times at the Nakonde border post. Public and private sector representatives collaborated to streamline customs procedures and reduce crossing times by 23 percent between 2011 and 2013. Prioritizing policy reforms that decrease border crossing times will make Zambian producers a more reliable source of agricultural products and therefore more attractive to regional and global markets.

DEVELOPING MAIZE VALUE CHAINS TO EMPOWER WOMEN AND YOUTH

In 2015, **DuPont Pioneer** and **Musika**, a non-profit Zambian company that supports private investment in smallholder agriculture, collaborated on the **Zambia Advanced Maize Seed Adoption Program (ZAMSAP)**, a community-based partnership to boost the productivity of small-scale maize farmers and facilitate their connection to maize markets. ZAMSAP is based on the highly successful Advanced Maize Seed Adoption Program (AMSAP), which has enabled tens of thousands of small-scale farmers in Ethiopia to increase their yields, reduce post-harvest losses and improve their livelihoods.

Farmers participating in ZAMSAP are provided with hybrid maize seed and advisory services, with locally managed plots demonstrating the yield benefits of hybrid seed over traditional recycled seed. Participants also receive training in basic agronomy and financial and market literacy in an effort to build their capacity to engage with financial institutions and commodity buyers.

ZAMSAP will develop and strengthen the maize value chain in the isolated markets of northern and northwestern Zambia, home to some of the poorest farmers in the country. Sixty percent of ZAMSAP participants will be women and youth who typically have limited resources and have little access to markets, yet they have the potential to drive agricultural development in these areas. The initiative will deploy women "lead farmers" and female company staff to help break down some of the traditional market barriers that prevent women farmers from reaching their full potential.

As the project develops, ZAMSAP will foster strategic alliances with commodity buyers to ensure that farmers benefiting from the productivity of hybrid seed will have access to secure and transparent markets for their increased crop production. ZAMSAP will also partner with farm input distributors to offer a holistic package of seed, fertilizer and crop protection products to farmers.

ZAMSAP expects to reach more than 100,000 farmers by 2018. With predicted yield increases of 100 percent, ZAMSAP can help transform a region of Zambia where economic growth is greatly needed. At the same time, ZAMSAP will strengthen the broader grain market, with financial benefits accruing to actors along the agricultural value chain, most notably the farmers.

Mrs. Nora Mubiana of the Chikakanta District, Southern Province, Zambia, admiring her 30G19 maize cobs. Photo source: DuPont Pioneer

INCREASING COTTON PRODUCTIVY IN AFRICA

Zambia has a large market-based cotton sector, mainly supplied by small-scale farmers. Agribusinesses have been training Zambian farmers to optimize their cotton production, yet annual cotton yields have not increased appreciably in the last 20 years. Improving cotton productivity could help Zambia expand and diversify its agricultural sector and increase incomes for producers.

African countries are beginning to expand their cotton production systems by adopting Bt cotton. Bt cotton is genetically modified to produce its own Bt (Bacillus thuringiensis) proteins that kill pests such as bollworm, one of the most destructive pests of cotton. The Bt proteins are toxic only to the insects which pose a threat to the cotton crop, and do not harm other beneficial insects, animals or humans.

Burkina Faso is home to more than 2 million people who depend on cotton production for a livelihood. Before the adoption of Bt cotton, small-scale farmers suffered huge losses due to pest damage. **Monsanto's** Bt cotton (Bollgard II) was commercially introduced to Burkina Faso after years of careful analysis of possible environmental, economic and social impacts. It has reduced pesticide use, lowered input costs, decreased the potential for runoff into surrounding watersheds, and the incidence of pesticide poisoning has declined. Since 2009, yields have increased by 25 percent and pesticide use has dropped by 66 percent.[73] The average economic effect was an increase in income of $137 per hectare.

IMPROVING LIVELIHOODS AND NUTRITION THROUGH AGRICULTURAL VALUE CHAINS

With rural poverty rates hovering around 80 percent, the majority of Zambia's agricultural producers are struggling with the triple burden of low productivity, poverty and malnutrition. The agricultural sector is a crucial factor to Zambia's economic development. With 70 percent of the population engaged in agriculture, increasing market-access for small-scale farmers is a priority. At the same time, 45 percent of the country as a whole is malnourished and there is a growing recognition that agriculture needs to become much more "nutrition-focused."

According to the **Geneva-based Global Alliance for Improved Nutrition (GAIN)**, the Zambian diet is mainly composed of cereals and starchy roots with little fruits, vegetables or animal products. As a result 30 percent of the women of reproductive age are anemic and almost half of the children under 5 years of age are stunted. Fifty-three percent of the children are deficient in Vitamin A and 46 percent are anemic, conditions that can lead to infection, compromised development and low productivity later in life.

NGO's, universities and the private sector are partnering on a variety of initiatives that demonstrate how nutrition-focused value chain development can improve the lives and livelihoods of Zambians by increasing their access to nutritious affordable food while raising their productivity and incomes.

CREATING A MARKETPLACE FOR NUTRITIOUS FOODS

The **Global Alliance for Improved Nutrition (GAIN)** sees an opportunity to bring its successful "nutrition-focused agriculture" models to the Zambian agribusiness sector to help build a responsive, profitable, accessible and safe food system. One such model is **GAIN's Marketplace for Nutritious Foods** which is providing African entrepreneurs in Kenya, Tanzania and Mozambique with business-planning and technical support to scale-up innovative enterprises that will increase the affordability, diversity and accessibility of nutritious foods to vulnerable populations.

Eric Muraguri is a Kenyan entrepreneur who studied food science before taking a job at **Ken Chic**, East Africa's largest poultry company. He noticed that the secondary chicken parts that could not be sold in the wealthy suburbs of Nairobi were being collected by poor women in the alley outside the slaughterhouse. Muraguri, who holds a master's degree in public health, knew these discarded parts could potentially be a source of healthy, safe protein for poor Kenyans. He began collecting, sanitizing and repackaging the undervalued bird parts and selling them at low margins. Today his four **Chicken Choice** shops, the first of which he opened in 2007, draw low-income consumers eager to carry home the once neglected parts in safe packaging at affordable price points.

Muraguri says his target market is women and children, who are the most vulnerable to malnutrition. "Men are able to access other protein sources during their work time, [but] women are often at home, so there is a need to bring nutritious foods closer to them." His vision is to make chicken products an affordable protein for every household in Kenya.

With business training and technical support from GAIN's Marketplace for Nutritious Foods, Kenyan entrepreneur Eric Muraguri is collecting, sanitizing and repackaging undervalued chicken parts from poultry companies and selling them through his Chicken Choice shops at low margins. His target market is women and children who are vulnerable to malnutrition. Photo source: GAIN

CONNECTING SMALL-SCALE PRODUCERS TO GLOBAL VALUE CHAINS

For small-scale farmers, accessing agricultural value chains is critical to the success of their businesses, but it is often the most difficult obstacle to overcome. Most rural producers in Zambia are geographically isolated from the major agricultural hubs. As a result they do not have efficient or affordable means to connect with agribusinesses that may be interested in purchasing their products. Additionally, many small-scale producers and suppliers lack the business and marketing skills they need to attract and retain customers who are further up the agricultural value chain.

PROFIT+ is a USAID-funded initiative, implemented by **ACDI/VOCA** in partnership with the government, farmer cooperatives and the private sector, that is working to bridge the "last mile" between small-scale producers and the agricultural value chain. ACDI/VOCA is working with more than 200,000 small-scale farmers in the Eastern Province of Zambia to improve their productivity in maize, soya, groundnuts, sunflowers, onions and tomatoes and to link producers to agribusinesses that participate in regional and global agricultural value chains. To improve their productivity, farmers are connected with local input suppliers who can provide them with the agricultural technologies and advisory services they need to increase the quantity and quality of their product.

Grace Nyirongo Phiri, a farmer in the Lusaka Province, is one of approximately 12,000 farmers who have received training and technology through PROFIT+. More than 200 of Phiri's neighbors have visited her thriving farm, complete with a greenhouse and drip irrigation, to see how she uses new agricultural technologies to manage disease and pests in her tomato and onion crops.

ACDI/VOCA has also developed a "Farming as a Business" curriculum and works in conjunction with agriculture cooperatives to provide farmers, suppliers and aggregators with training in post-harvest handling, record keeping, financial management and customer relations.

To increase market access, ACDI/VOCA encourages national and international agribusinesses to source from smaller producers by expanding their value-added processing facilities to rural areas. Not only does this shorten the distance to market for farmers, the value-added facilities create employment opportunities in rural areas where the rates of poverty are the highest.

Through PROFIT+, Zambian producers who previously sold to local markets are increasing their incomes and moving out of poverty. Perhaps most importantly, they are reinvesting in their own businesses and developing new agri-enterprises that create employment and economic development.

Photo source: ©IFAD/Siegfried Modola

LIVESTOCK PROGRAMS BREAK THE CYCLE OF HUNGER IN ZAMBIA'S COPPERBELT

One of the keys to reducing malnutrition, particularly for children, is to increase their consumption of animal-based proteins such as meat, milk and eggs. Livestock ownership can provide access to these nutrient-dense foods and also provide a source of regular income, which reduces poverty and improves nutrition particularly for women-headed households.[74] **Heifer International**, the **University of Illinois at Urbana-Champaign** and **Elanco Animal Health** have partnered with communities in the Copperbelt Province — the heart of Zambia's mining sector — to implement a livestock development program that is reducing poverty and improving nutrition and food security. The key to success is to combine a livestock donation from an organization such as **Heifer Zambia** with a program of social capital building through community groups and farmer cooperatives, to give project participants access to support services such as extension and finance, as well as access to markets.

An evaluation of the Copperbelt project by the University of Illinois shows that the livestock donation program significantly increased household livestock revenue by 200 percent or more, household food expenditures by more than 35 percent and dietary diversity by adding at least one additional food group to the household's daily diet.[75] The nutrition and food security impacts were felt by other residents in the villages who now have greater access to animal proteins, such as milk. Overall, participants reported an improved sense of food security, even though their income status had not yet changed substantially. As the community works together to gain access to finance and markets, these families will become financially self-reliant with the ability to plan for an even brighter future.

FOOD SECURITY THROUGH AGRO-FORESTRY AND ANIMAL CONSERVATION

Community Markets for Conservation (COMACO) is a Zambian-led organization working to improve rural livelihoods and food security while also making effective contributions to landscape and animal conservation. More than 100,000 farmers have signed conservation pledges and are learning how to integrate conservation with farming while improving their incomes. Farmers are cooperating with local leaders to develop Community Conservation Plans to reduce the impact of farming and land clearing activities on natural resources. Customary authorities have convened community meetings to secure support for creating Community Conservation Areas, where intact forests are protected from further settlement or farming. To date, approximately 1 million hectares have been protected in this way.

Some 1,500 COMACO farmers are former poachers who made ends meet by illegally poaching animals and cutting down forests for charcoal. In exchange for turning in their guns and wire snares (80,000 snares have been collected so far), COMACO provides training in agriculture, carpentry, food processing and beekeeping.

COMACO also promotes sustainable forestry. Instead of cutting down trees to make charcoal, 15,000 COMACO farmers now practice agroforestry, using wood grown on "tree lots" for their stoves instead of cutting trees from surrounding natural forests. More than 30,000 households are using fuel efficient stoves which further reduces pressure on fragile forests.

Some of the COMACO farmers who are integrating conservation techniques into their crop and livestock farming. Photo source: COMACO

COMACO has also developed poultry centers which process and sell chickens produced by local farmers, increasing their incomes by 44 percent. With the support of veterinary educators from **Cornell University**, COMACO instituted a vaccination program to reduce the incidence of Newcastle disease, which was killing up to 60 percent of the chickens each year. Thanks to the vaccinations and education efforts encouraging farmers to provide birds with water, supplemental food and improved housing conditions, the average family poultry flock has tripled in size.

REALIGNING AGRICULTURE TO IMPROVE NUTRITION

Reducing malnutrition in Zambia is a priority, particularly the incidence of child stunting, a shortness of stature resulting in irreversible impairments from mental and physical underdevelopment. Those at greatest risk for malnutrition are subsistence and small-scale producers who have high rates of poverty and HIV/AIDS, and limited access to nutrient dense foods, such as green leafy vegetables.

Concern International, in collaboration with the Zambian ministries of agriculture and health, has been working with families in the Mumbwa District in the Central Province to diversify their diets and educate women and men about the critical importance of good nutrition, particularly in the first 1,000 days of life, from pregnancy to the age of two. Participants in the **Realigning Agriculture to Improve Nutrition (RAIN)** project received inputs (including vegetable seeds and small livestock) and training to develop household gardens and animal husbandry. Nutrition education stimulated an increase in the consumption of vegetables by participants and men were encouraged to support women's efforts to diversify the family's diet.

An evaluation of the five-year project conducted in 2015 revealed increases in the production of nutrient-rich foods, diet diversity and the decision-making power of women within the household. **One of the keys to success was community-level collaboration between agriculture extension agents, health workers and the women's groups that provided a focal point for community engagement and knowledge sharing**. The RAIN project demonstrates how diversifying and increasing agricultural production can change the lives of rural Zambians struggling with the triple burden of poverty, low productivity and malnutrition.

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