2016 GAP REPORT®

GLOBAL AGRICULTURAL PRODUCTIVITY REPORT®

Sustainability in an Uncertain Season

GLOBAL HARVEST INITIATIVE

2016 Global Agricultural Productivity Report® (GAP Report®)
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GHI dedicates the 2016 GAP® Report to the memory of **David P. Lambert**, a leader in the fight to end global hunger and promote nutrition.

GLOBAL HARVEST INITIATIVE

Global Harvest Initiative (GHI) was formed in 2009 as a **private sector policy voice for increasing productivity and sustainability throughout the agricultural value chains for food, feed, fiber and fuel.** We believe the right policies, practices and technologies improve global food and nutrition security, accelerate productivity, reduce waste and loss, conserve natural resources and mitigate climate change.

GHI advocates a comprehensive approach that emphasizes increased productivity, access to nutritious food, improving incomes for producers, and strengthening the productivity and resilience of farmers. GHI particularly recognizes the critical role that women farmers and pastoralists play as engines of productivity and food security.

GHI's member companies are DuPont, Elanco Animal Health, Farmland Partners Inc., 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, Conservation International, Farm Foundation, Global Alliance for Improved Nutrition, Inter-American Development Bank, Inter-American Institute for Cooperation in Agriculture, The Nature Conservancy, New Markets Lab, Purdue University School of Agriculture, Robert B. Daugherty Global Water for Food Institute at the University of Nebraska, Supporters of Agricultural Research Foundation and the World Wide Fund for Nature.

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LETTER FROM THE EXECUTIVE DIRECTOR

Sustainability in an Uncertain Season

The business of agriculture is cyclical. Political, environmental and economic headwinds create volatile and unpredictable swings. Agriculture systems must respond to both sudden shocks and smoldering crises that impact the livelihoods of producers and food security for consumers.

In 2008-2009, a global surge in food prices that pushed millions into hunger galvanized attention to this issue. Today, by contrast, lower global commodity prices and sufficient stockpiles have created a new and different set of challenges for producers, the wider agricultural industry and policymakers.

Drought and shifting climate patterns across southern and eastern Africa and intense heat waves throughout the Indian subcontinent are creating regional food shortages. Conflict within fragile states has created significant threats to peace and food security, and geopolitical forces threaten the coherence of political institutions and economic alliances, giving rise to investment uncertainty. Indebtedness places pressure on government budgets, resulting in stagnating investments in agricultural research and development and extension.

And globally, nearly 800 million people continue to go hungry, with two billion people suffering from malnutrition and poor health — many are small-scale farmers themselves.

Today's food and agriculture system must rise to the challenge of improving productivity to meet growing demand while becoming increasingly focused on sustainability.

Our challenge is clear. How can we manage through the current storms and foster more sustainable inclusive growth during the agricultural business cycle, both now and in the years ahead?

Our response and top priority must be to **foster productivity and competitiveness throughout the agricultural value chain and in every phase of the business cycle**. All participants in the value chain, regardless of scale, need to be able to manage costs and risk, invest for innovation and growth, and continue to collaborate so the world can more sustainably produce sufficient nutritious, affordable food, as well as feed, fiber and biofuel for our growing global population.

The *2016 Global Agricultural Productivity Report® (GAP Report®)* advocates policies and innovations in five key areas to help the agriculture and food sectors manage uncertain seasons of fluctuating business cycles and climate change, while fostering competitiveness today and sustainable growth tomorrow.

Margaret M. Zeigler

Dr. Margaret M. Zeigler
Executive Director
Global Harvest Initiative

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THE GLOBAL AGRICULTURAL IMPERATIVE

By 2050...

A rapidly expanding urban and middle-class population will demand more food for people, feed for animals, fiber for clothing and forest products for home and industrial use, as well as biofuels for energy.

Between 2010 and 2050, we will have to **nearly double all agricultural output** to meet this growing demand.[1]

Yet **volatility in economic markets,** environmental pressure and **climate change**, and the rise of **conflicts in fragile regions** pose threats.

The challenges are clear: how can we manage the storms, produce what we need through sustainable practices, ensure equitable access to food and foster good health and inclusive economic growth?

VOLATILE AGRICULTURAL BUSINESS CYCLES

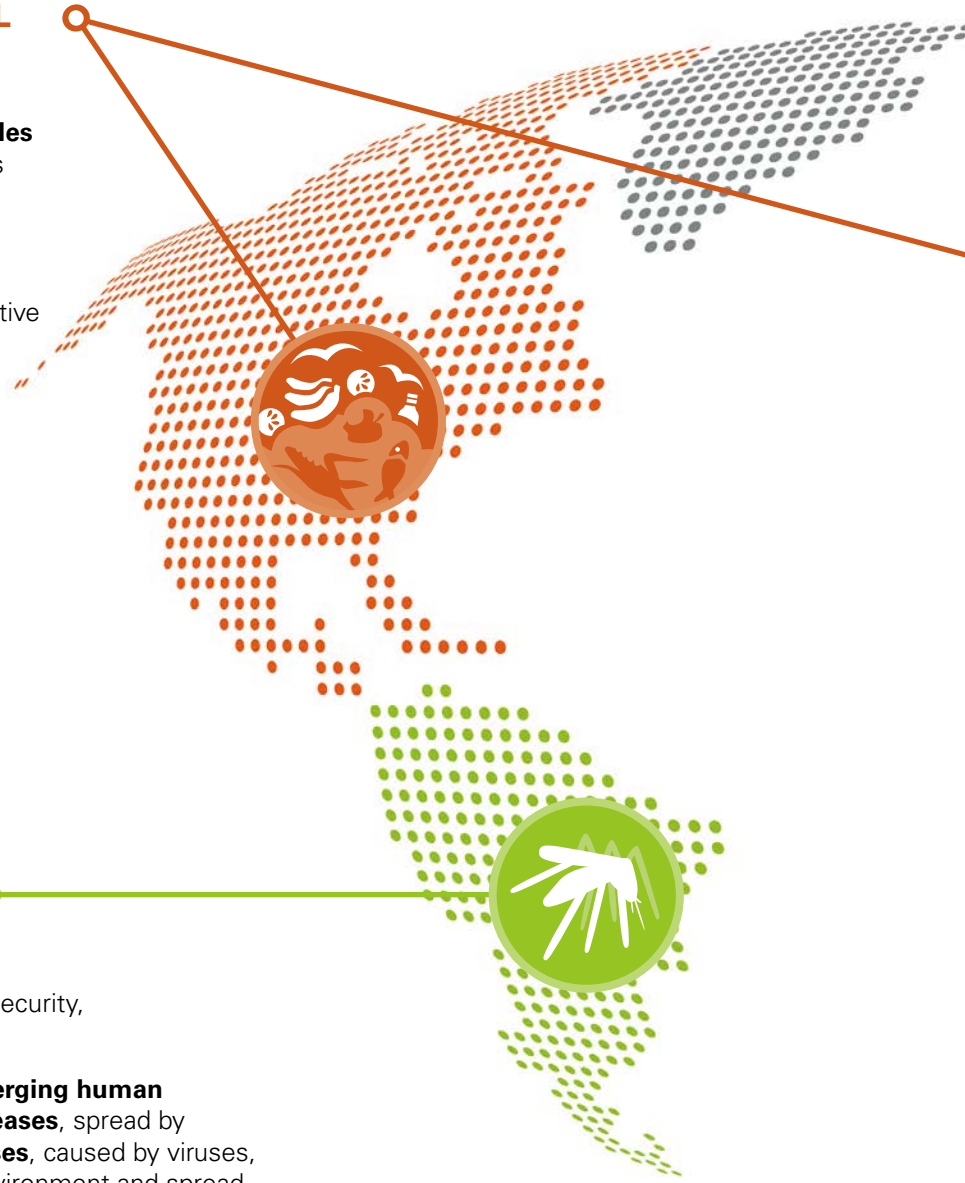
Global economic forces of **supply and demand create volatile business cycles** that pressure farmers and agribusiness from one season to the next.

Stagnating public investments for agricultural R&D and **infrastructure** create long-term challenges for productive agriculture value chains, raising costs for producers and consumers.

Outdated regulatory systems and lack of access to finance stifle innovation resulting in waste, inefficiency and greater greenhouse gas emissions.

Up to **50% of fresh, nutritious produce is wasted** in the U.S.[2]

Barriers to trade in agriculture raise the cost of goods and services and exclude producers from market opportunity.

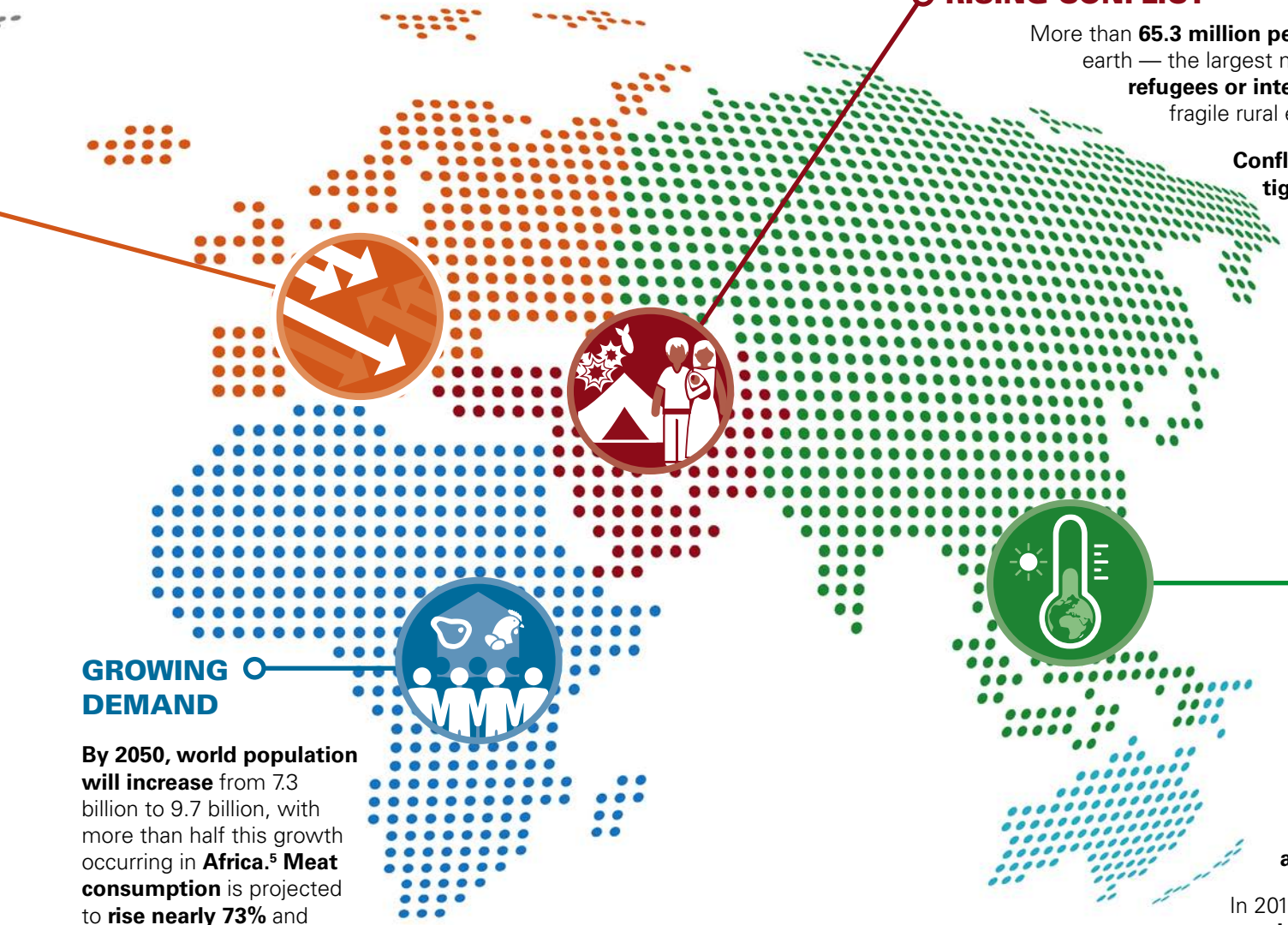


VULNERABLE HEALTH

The symbiosis among **human, animal and biosphere health** is creating new opportunities and challenges for food security, nutrition and disease prevention.

At least **75% of emerging and re-emerging human diseases are either vector-borne diseases**, spread by ticks or mosquitos, or **zoonotic diseases**, caused by viruses, bacteria, parasites, and fungi in the environment and spread between animals and humans.[3]

Malnutrition and poor diets are now the largest risk factors responsible for the global burden of disease; 45% of deaths of children under age 5 are linked to **malnutrition**, and nearly **2 billion adults are overweight or obese**.[4]



RISING CONFLICT

More than **65.3 million people, or 1 out of every 113 people** on earth — the largest number since World War II — are now either **refugees or internally displaced** due to conflict, poverty or fragile rural environments.[9]

Conflict, migration and drought are becoming tightly interwoven in the Middle Eastern region, with evidence that the 2007–2010 drought contributed to the conflict in Syria.[10] Prolonged conflicts continue in many countries throughout the region and across Africa.

Unprecedented need for humanitarian assistance strains donor country development budgets, reducing available resources for agricultural development programs.

CHANGING CLIMATE

Rising temperatures and shifting weather patterns are impacting soil and water resources for agriculture. **Fragile drylands and tropical areas** are particularly vulnerable.

Today **4 billion people face annual water scarcity:** nearly **2 billion of these are in China and India**.[11]

In 2015–2016, **El Niño** weather events caused **severe droughts** throughout Africa, Asia and the Americas.[12]

Agriculture uses 82% of freshwater in Africa and 81% in Asia; this will rise to an average of **89% by 2050**.[13]

Opening up new land for agriculture **reduces biodiversity and releases carbon** stored in soils. Poor land management contributes to **land degradation**, further reducing soil and water productivity.

GROWING DEMAND

By 2050, world population will increase from 7.3 billion to 9.7 billion, with more than half this growth occurring in **Africa.[5] Meat consumption** is projected to **rise nearly 73%** and **dairy consumption by 58%** over 2010 levels.[6]

Urban areas will grow by more than 2.5 billion people — half the world is urban now, and two-thirds will be urban by 2050.[7] Ninety percent of these new urban dwellers will reside in Africa and Asia.[8]

Available labor for food production will decline as young people leave rural areas for cities.

recommendations

How can we foster sustainability, health and inclusive economic growth in an uncertain season?

With a **long-term commitment** to the right policies, investments and science-based technologies and practices,

WE CAN ...

Build Resilience

Invest in agricultural productivity, helping farmers of all scales build stable businesses and remain competitive during volatile business cycles.

Foster an Inclusive, Thriving World

Farmers participate in new markets and consumers access food diversity through better trade, infrastructure and transparent information.

End Hunger

The global number of hungry people could be reduced by as many as 135 million if women had equal access to productive resources.[14]

Improve Nutrition & Health

Build human capital through investments in basic and higher education so future generations can harness advancements in food production and agrotechnology.

Regenerate the Environment

Regenerate the natural environment through completely new bio-innovation economies that supply food, create jobs, reduce waste and improve health.

The Agricultural Business Cycle: Managing Through the Booms and Busts

Long-term global trends point to a growing demand for food and agriculture products due to an increasing population and an expanding middle class. The ups and downs of the global economy, along with the particular boom and bust cycles that have long affected the agriculture sector, will continue to impact farmers and other agriculture value chain (AVC) participants such as seed, fertilizer, crop protection and machinery suppliers, agricultural financial services, buyers, processors and retailers.

In response to these cycles, farmers and other AVC participants can manage their risk, reduce waste and loss, cut costs and identify new market opportunities. Government and private industry can provide additional risk management tools and safety nets.

Understanding the drivers of these cycles and helping agricultural value chain participants prepare for volatility — while building stronger, more competitive operations — is a strategy to manage through the inevitable storms and ensure longer-term business success. It also involves getting the right public policies in place, along with a dedicated commitment to increasing productivity throughout the agricultural value chain, with the goal of fostering resilient, sustainable and successful operations that provide needed food and agriculture products for a growing world.

Figure 1: Real Agricultural Prices, 1900–2015

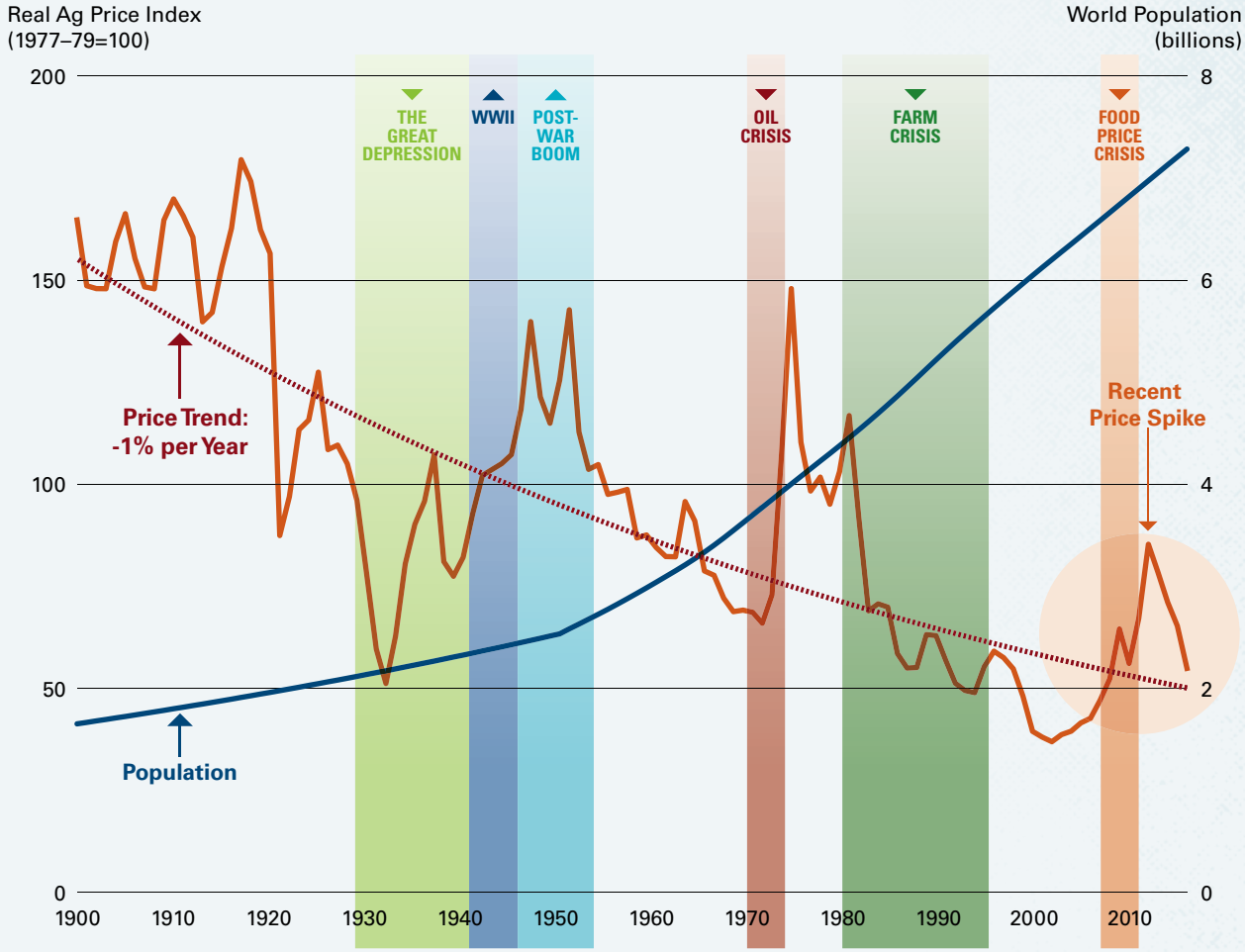


Figure 1 depicts the Grilli-Yang agricultural price index adjusted for inflation by the U.S. Gross Domestic Product implicit price index. It is a composite of 18 crop and livestock prices, weighted by its share of global agricultural trade (Pfaffenzeller et al., 2007). World population estimates are from the United Nations.

Source: USDA, Economic Research Service using Fuglie, Wang, and Ball (2012).

Drivers of Agricultural Business Cycles

As Figure 1 depicts, since 1900, real agricultural commodity prices have fallen, while world population growth more than quadrupled to 7 billion in 2015. The average price reduction trend has been one percent per year over that time. But shorter-term boom and bust cycles are apparent within this long-term trend.

In the last decades of the nineteenth century and first two decades of the twentieth century, technological changes, population growth and migration set the stage for increased trade and integration, sparking the "first wave of globalization."[15] Global demand and prices for agriculture goods were relatively high until 1929. With the onset of the **Great Depression** in the 1930s, prices for agriculture goods dropped and trade slowed as economies contracted.

Prices for agriculture products rebounded during the booming **World War II** era, as demand rose for food, animal feed, fuel and goods for manufacturing. During the post-war era, there was a nearly two decade-long period of global growth, during which the world per capita economy grew at about 2.9 percent annually. The creation of the Bretton Woods institutions, investments in reconstruction of Europe and Japan, and the creation of new global trade structures such as the General Agreement on Tariffs and Trade (GATT) spurred trade expansion and financial integration.[16]

Commodity prices soared in the **1970s**, sparked by the oil crisis, droughts and Soviet purchases of 10 million tons of U.S. wheat and corn following a failed grain harvest. Monetary policies with higher interest rates attempted to control rising inflation, and by the 1980s a debt-crisis emerged and a bust cycle began. In the United States, many farmers who had purchased land, equipment and other capital investments were locked into high interest rate loans, spurring the **1980's Farm Crisis**. International trade slowed as the Soviet Union invaded Afghanistan and an embargo of agriculture exports from the United States placed additional strain on farmers. Many of them lost their farms due to debt and bankruptcy, requiring relocation and a search for work off the farm.

Over the period from the early **1990s until 2007**, economic growth and agricultural prices rebounded, with global economic per capita growth averaging 2.4 percent annually.[17] Economic and financial integration, access to lower interest loans and capital, new technologies and the movement of goods, services and people all served to stimulate this recovery, which included a rise in agricultural prices. The second wave of globalization had begun, with increasing trade and economic integration. Even with the shock of the **2008 financial crisis** and global recession, agriculture prices managed to remain high, reflecting continued high food demand from countries like China.

A severe **food price crisis** began in 2007 due to high food demand from a growing global middle class, increased use of biofuels, a series of weather-related poor harvests in exporting countries, high cost of energy and diminishing grain stocks. Prices of basic staple food crops, particularly rice, spiked upwards. Almost overnight, hundreds of millions of low-income people across Asia, Africa and parts of Latin America were unable to afford food, setting off political unrest and driving conflict and migration. Farmers in major producing countries were able to export grains and earn record profits from 2008 through 2013.

Due to sufficient global supply and slightly lower demand in China, prices of commodity crops began a downward trend in 2014 that continues through 2016.

SUSTAINABILITY IN AN UNCERTAIN SEASON

Farmers around the world are impacted differently by the agricultural business cycle. How they respond to downturns — particularly when it comes to building resistance against future shocks — typically depends on their level of education, training, access to finance, information and technology, and supportive public policies that enable them to compete and take advantage of market opportunity.

Governments must help by providing essential public goods such as infrastructure, agricultural research, development and extension services and access to credit and risk management services. Fair and efficient trade can help farmers supply new markets.

African Farmers Face Drought and Debt

The "benevolent decade" of growth in Africa from 2000 to 2010 has now reversed, with lower currency values in many African countries, growing debt from unrestrained borrowing, China's slowdown of demand for commodities and extreme weather events. Smallholder livestock and poultry farmers in parts of Africa hit by the recent El Niño drought are facing skyrocketing prices as maize crops for both human food and animal feed have withered and failed. Agricultural producers are turning to remittances from family members abroad, selling assets and putting off investments in new productive technologies. Some are seeking work off the farm, pulling children from school, or resorting to high risk behaviors including regional or international migration and sex work. Governments can help by instituting social safety nets, partnering with the international community to provide emergency food and cash assistance, and increasing investments in rural development and agriculture.

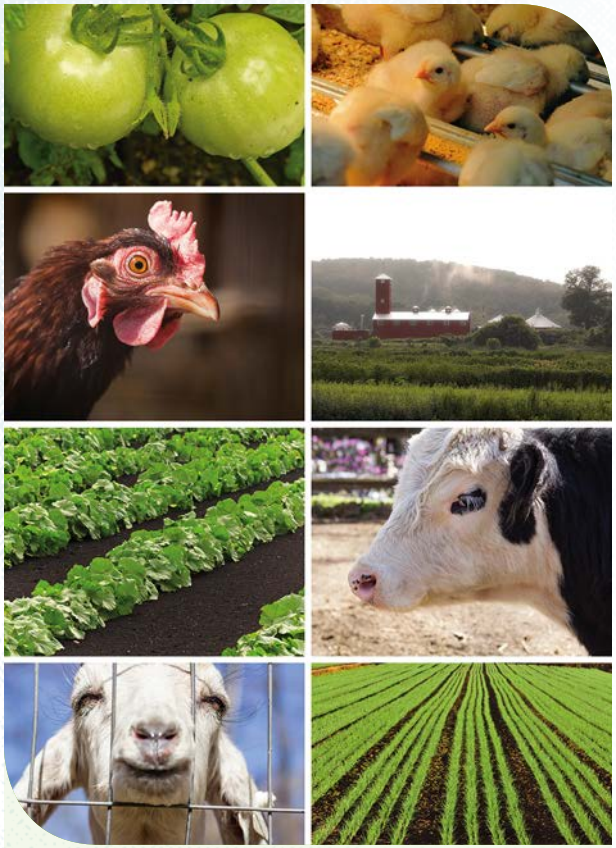
U.S. Farmers Tighten Their Belts

Many farmers in the U.S. are concerned about low crop prices, high land rents and prices for seeds, fertilizer, machinery and storage. Uncertainty about environmental regulations are making it more challenging to plan for the future, and they are concerned about negative consumer perception of some of their agricultural practices. Farmers are reducing costs by delaying purchases and supplementing incomes with off-farm jobs. New types of partnerships are another solution, including contract farming and collaborative cost sharing. At present, loan interest rates are historically low and many farmers participate in farm insurance programs to reduce risk. There are options to participate in government conservation programs to protect soil and water resources and be rewarded for these environmental services.[18]

Finding Strength in Numbers

Women small-scale farmers provide most of the labor for planting, cultivating and harvesting crops, yet they rarely own or manage the household's agricultural inputs including land, water, seed, fertilizer, crop protection and machinery. At a time when controlling costs is essential, discriminatory cultural norms deny women decision-making authority over the very assets that would help them remain competitive. Women sugarcane farmers in Paraguay have formed cooperatives through which they access credit and purchase inputs for themselves. The cooperative provides training to help the women increase their productivity. The women gain control over their incomes by selling collectively to traders, which ensures they receive a fair price. Leadership skills developed through the cooperative encourage women to take a larger role in civic life, but gender discrimination still suppresses the productive potential of women and the health and welfare of their families.

During the volatile business cycles of agriculture, farmers must explore every opportunity to cut costs, improve their production and business practices and wisely manage their natural resource base such as soil, water, livestock and farming operations for long-term sustainability. A key strategy is to focus on **effective business planning, data management for decision support** and **productivity to stay competitive in volatile business cycles.**



WHAT IS SUSTAINABILITY IN AGRICULTURE?

Sustainable agriculture must satisfy human needs; enhance environmental quality and the natural resource base; sustain the economic viability of agriculture; and enhance the quality of life for farmers, ranchers, forest managers, fisherfolk, workers and society as a whole.

Source: National Research Council, *Toward Sustainable Agricultural Systems in the 21st Century,* (2010).

Productivity and Innovation: Sustainable Agricultural Growth in an Uncertain Season

The United Nations' 17 Sustainable Development Goals (SDGs) took effect at the beginning of 2016, launching the countdown to achieve inclusive, sustainable development and economic growth by 2030. Many SDGs have clear implications for agriculture, while agriculture and forestry play a central role in the strategy to achieve many of the goals.

Most notably, Sustainable Development Goal 2 calls the world community to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture." As part of a comprehensive set of actions the UN's 2030 Agenda for Sustainable Development calls for **"doubl[ing] the agricultural productivity and incomes of small-scale food producers,** particularly women, indigenous people, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets, and opportunities for value addition and non-farm employment."[19]

Accelerating agricultural productivity must be at the core of a comprehensive strategy to sustainably feed the world through a regenerative system of agriculture and food production. With more than three-quarters of the world's poor being heavily dependent on agriculture for their direct subsistence food needs as well as for their incomes, agricultural development through productivity improvements and higher incomes is one of the most powerful ways that farmers, pastoralists and fishers can rise out of poverty and improve their nutrition and health.[20] Productivity benefits producers of all sizes by improving the resilience and competitiveness of their operations. Productivity also enables better stewardship of land, water and other natural resources.

Productivity itself is not simply producing more food, or even achieving higher yields. 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 in agriculture lowers the cost per unit of output, helping producers succeed in today's competitive business cycle, and enables agri-food systems to provide foods for consumers at lower prices.

Total Factor Productivity: A Measure of Innovation Adoption

To meet growing market demand, and in alignment with local agro-ecological and economic conditions, producers often look at the following options to increase their production output:

» **Expansion of Land** — They can use more land to produce more, and in some cases convert forest to cropland or rangeland.

» **Irrigation** — They can deploy or extend irrigation systems to cover more land to protect against drought and improve its productive capacity, and in some cases permit multiple cropping.

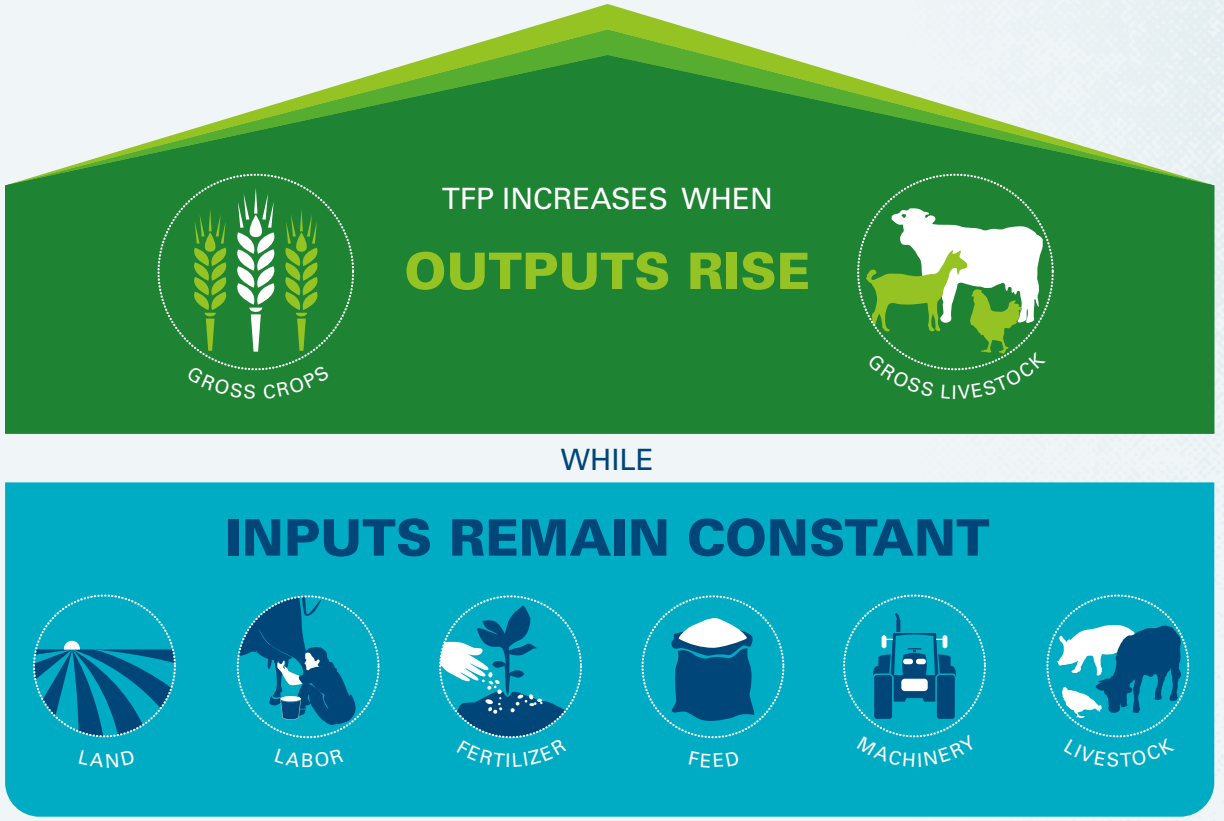
» **Intensification** — They can increase applications of fertilizer, machinery, labor, seeds, herbicides or other inputs on land to grow more crops or raise more livestock.

In light of the growing demand for food, feed, fiber and fuel over the next few decades and the need to manage and mitigate environmental impact, it is clear that global agriculture must continue to shift its focus toward another option:

» **Efficiency** — Adopting technologies and production practices that result in more output from existing resources, as measured by **Total Factor Productivity (TFP).**

TFP (Figure 2) 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. Producers, governments and agribusinesses who pursue this course are not just interested in whether agricultural output is growing, but to what extent increased output is due to **better use of existing resources through the application of improved products, technologies and practices — essentially, how *innovative* their operations are.** 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 production systems, how to make investment decisions and what policies support more productive and sustainable agriculture.

Figure 2: Total Factor Productivity



Productivity and Innovation in Practice

For **crops**, improved TFP results from adopting innovations like higher yielding, pest-resistant and/or drought and flood tolerant seed varieties. The growing bio-innovation sector includes precision use of microbes (bacteria and fungi) to help crop farmers generate more yield on the same land. Microbes also protect plants from dry conditions and increase yield, as well as protect plants from pests. TFP is also improved by practices and knowledge that enable more efficient and timely cultivation techniques, and by using precision data and information technologies in farm equipment to target applications of fertilizer, water and crop protection.

In **livestock production**, TFP increases when favorable genetic qualities in animals are selected and bred, and when animals receive better overall husbandry, vaccinations and high quality feeds that deliver more nutrition per volume. In **forestry**, genetically improved trees provide faster-growing products for earlier harvesting and more volume per tree.

Ensuring that farmers and producers of all scales and sizes gain access to better innovation technology and training and knowledge for best practices will help foster greater TFP and reduce impact on the soil, water and air quality, as well as effectively use increasingly scarce labor in agricultural operations.

TFP Global Trends

Placing productivity growth as a central policy goal can accelerate economic growth and raise incomes. As productivity growth increases, it allows laborers to produce more with less time, freeing up both labor and capital investments to move into other industries to produce more or different goods and services.

Over the past century, the development and adoption of advanced hybrid seeds and new machinery and equipment helped make individual farm operations more productive, providing more food per area of land and per laborer. Extending these technologies and practices, including irrigation, application of fertilizer and crop protection products to developing countries in the 1960s through the work of scientists such as Dr. Norman Borlaug, marked the start of the Green Revolution. Through intensification of production, many countries such as India, Mexico and Pakistan were able to greatly reduce hunger and famine within the span of a decade.

In the 1980s, thanks to the collaborative work of national agricultural research systems (NARs), private sector agriculture businesses, and global institutions such as the CGIAR (Consultative Group on International Agricultural Research), continuing improvements and refinements in agricultural technology began a more sustainable trajectory for agriculture production. 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 investments and innovation — are now accelerating productivity, as measured by TFP[21] (Figure 3).

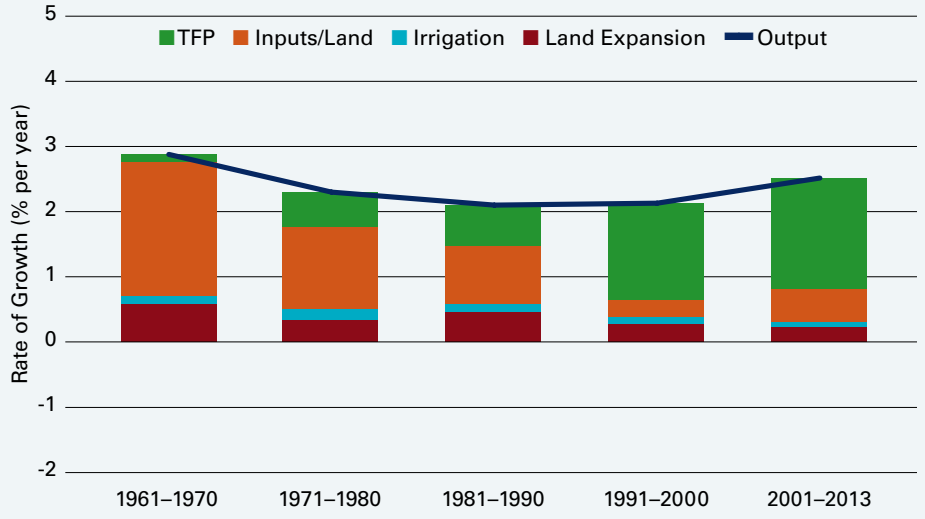
In the last decade, rapid advancements in biotechnology and bio-innovation, along with digital data systems and information technologies, are allowing even greater accuracy in choosing and applying inputs to match local agro-ecological conditions, thereby helping farmers conserve resources and adapt to climate change and volatile weather. Precision data systems provide timely information about specific soil, crop, livestock and forestry challenges, enabling farmers and producers to make decisions that boost their output while reducing the amount of time that machinery and equipment are used and maximizing the benefits of fertilizers and irrigation and crop protection. Precision data also helps target more accurately the right amounts of feed and health care products for livestock, customizing animal husbandry. New technologies and data can also help reduce food loss and waste.

Over the past five decades, TFP has accounted for a growing share of the growth in agricultural output globally, while the contribution of other inputs

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 3: Sources of Growth in Global Agricultural Output, 1961–2013



Source: USDA Economic Research Service (2016).

(fertilizer, machinery, feed, labor and crop protection) to output growth reduced dramatically. **On average, efficiency and innovation are beginning to account for a greater proportion of agricultural output worldwide.**

TFP Variation by Income

While Figure 3 indicates that TFP is a larger share of agricultural output globally in recent decades, Figures 4 and 5 show there is considerable variation across countries, particularly when considering per capita income and development levels.

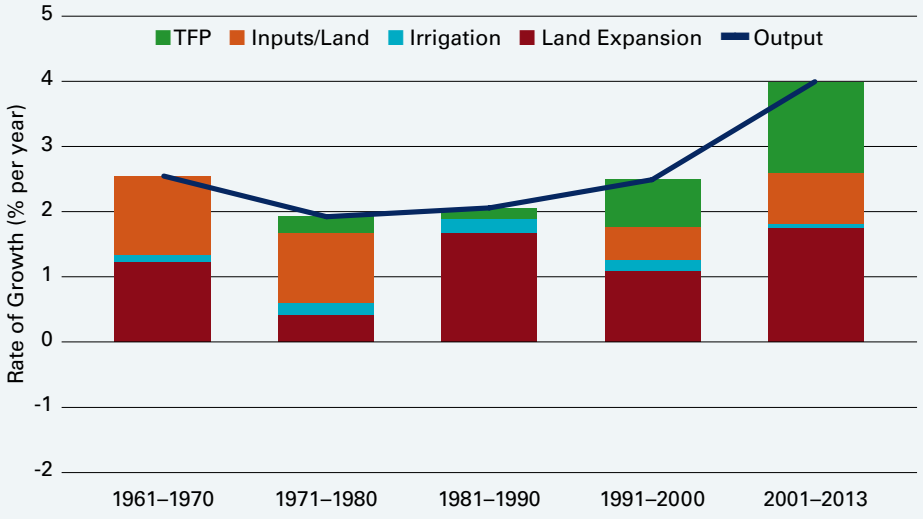
Low-income countries have boosted their agricultural output dramatically since the mid-1980s, and a growing share of their agricultural output is now attributable to TFP, or more efficient production (Figure 4). Nonetheless, a significant share of production in low-income countries is still from intensification of input use and expansion of land used for agriculture. Land-use conversion, particularly in fragile dryland or tropical forest zones, can accelerate carbon release and land degradation, contribute to erosion and damage critical ecosystems.

Raising productivity in low-income countries under the TFP approach will require increasing and sustaining investments in agricultural research and development (R&D), more effective knowledge transfer, training and extension services, expansion of rural infrastructure and access to finance for farmers, and value chain development. 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 innovation.

Support from the international community, including joint research, technology transfer and building capacity of local communities, institutions and business, will foster inclusive agricultural growth and better nutrition. Public-private partnerships can be tailored to provide investments meeting the special needs of smallholder farmers, women, cooperatives and producer associations.

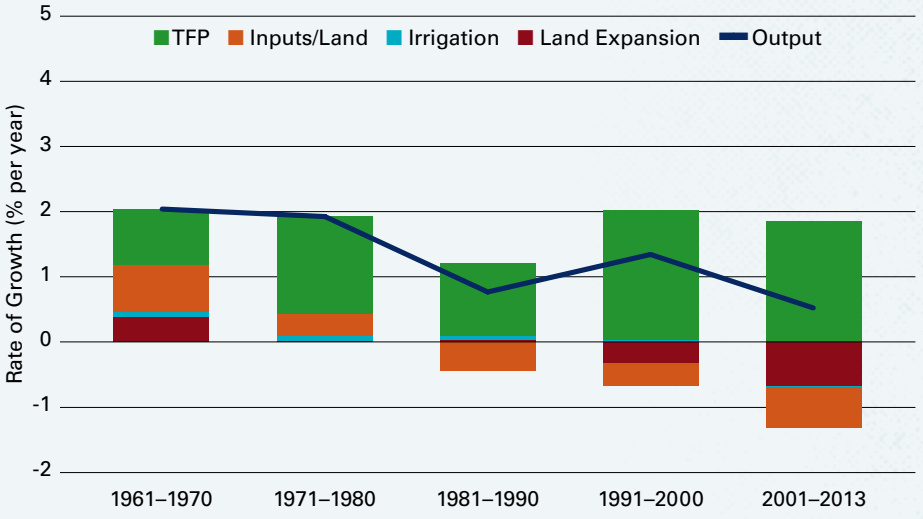
In high-income countries, decades of public and private investments in agricultural research and development, extension services and rural infrastructure, along with adoption of innovations in crop and livestock genetics, have made TFP the principal source of growth in agricultural output (Figure 5). Use of land in agriculture has contracted, allowing land to be placed in 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 TFP growth. With new technologies on the horizon such as precision agriculture and data systems to support farmers, this trend may be reversed.

Figure 4: Sources of Growth in Agricultural Output: Low-Income Countries, 1961–2013



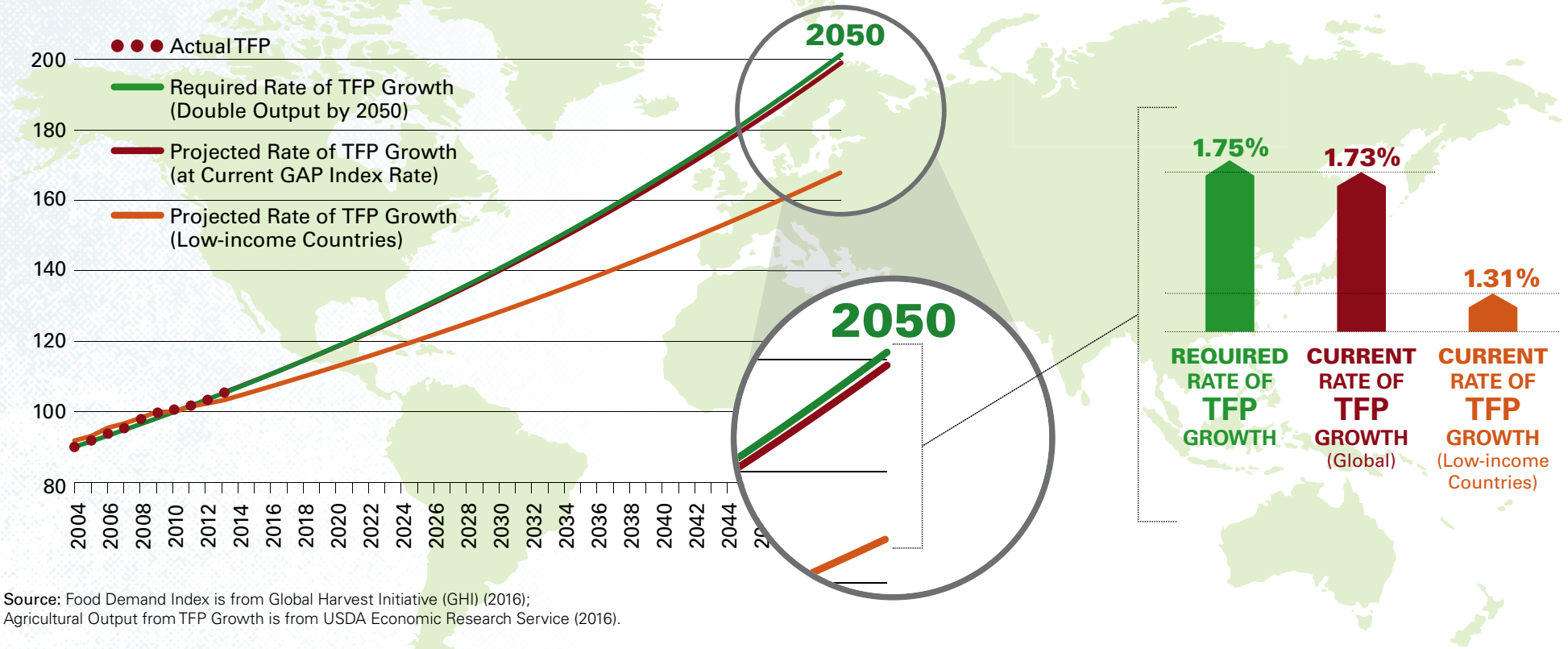
Source: USDA Economic Research Service (2016).

Figure 5: Sources of Growth in Agricultural Output: High-Income Countries, 1961–2013



Source: USDA Economic Research Service (2016).

THE GLOBAL AGRICULTURAL PRODUCTIVITY (GAP) INDEX™



Source: Food Demand Index is from Global Harvest Initiative (GHI) (2016); Agricultural Output from TFP Growth is from USDA Economic Research Service (2016).

The GAP Index

In 2010, GHI calculated that **global agricultural productivity (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 meet the growing global demand, experts are concerned that this production will come at the expense of the environment and natural resource base. In addition, agriculture production of livestock and crops contributes to greenhouse gas (GHG) emissions, further accelerating climate change.

The 2016 GAP Index™ reveals that for the third straight year global TFP growth is not accelerating fast enough to sustainably double agricultural output by 2050.

U.S. Department of Agriculture's Economic Research Service (USDA ERS) estimates that since 2004, TFP growth globally has been rising by an average annual rate of only 1.73. While the global growth rate is close to the target over the last decade, **TFP growth has been stagnating in the lowest income countries at only 1.3 percent, well below the SDG 2 target of doubling productivity for smallholder farmers in the lowest income countries.**

The impact of this productivity gap for low-income, food-deficit countries (where population growth is rapidly rising) will place strains on the resource base and may lead to more food 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 they will also impact rural populations, since they are net food buyers.

Accordingly, the lack of productivity growth may lead to farmland expansion, opening up fragile tropical forests and increasing the loss of wildlife habitat and biodiversity, as well as competition for existing water resources. And in dryland areas, the lack of productivity and climate-resilient practices will further degrade crop and rangelands, forcing many producers to abandon rural areas and migrate to cities and other countries.

Spotlight on Regional Productivity Gaps

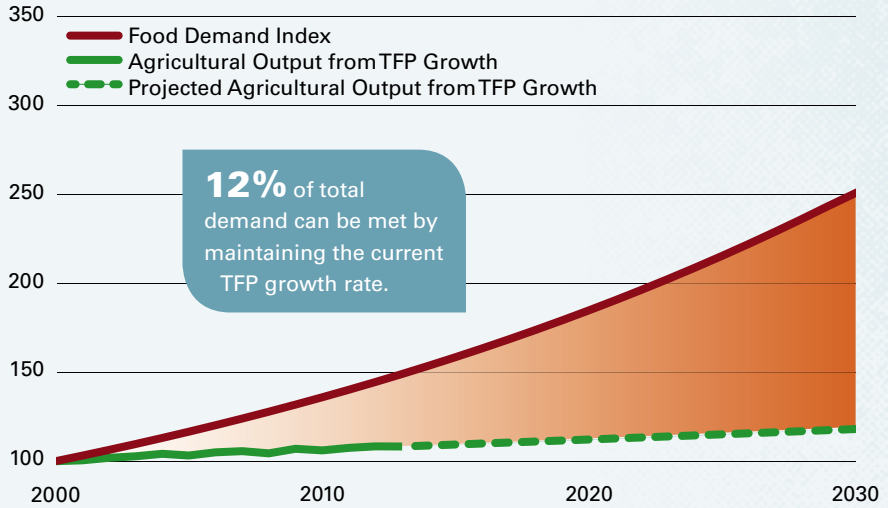
Regional differences in productivity growth illustrate areas of special concern. In the *2012 GAP Report®*, GHI established a series of regional estimates comparing food demand indexes against projected agricultural output from TFP growth for the period 2000 to 2030. Figures 6 and 7 update two of these estimates (for Sub-Saharan Africa and Latin America).[22] If current trends continue, there will be **insufficient growth in TFP to meet estimated future demand through productivity in Sub-Saharan Africa (SSA). The gap in this region will be 88 percent, with only 12 percent of the increase in food demand met through productivity by 2030.**

Global trade is likely to expand over the coming decades and this will greatly influence the extent and nature of food security, as trade will play a key role in closing the gap between areas of high food demand (such as SSA) and those areas that can serve to supply more food, feed, fiber and fuel. SSA already imports 50 percent of its vegetable oils, 35 percent of its poultry meat and 23 percent of its sugar requirements.[23] Without productivity growth, regions like SSA and the Middle East and North Africa will be increasingly dependent on trade for basic food commodities, as well as high value foods.

The Latin American region and particularly the southern cone nations of Argentina, Brazil, Paraguay and Uruguay (ABPU) comprise the world's largest net exporting zone of agriculture products.[24] These countries and others in Latin America have the potential to vastly increase their productivity to sustainably supply food and other agricultural goods to a growing world (Figure 7). Harmonizing trade rules and improvements in supply chains and infrastructure will enable more timely and beneficial trade to close the future gaps.

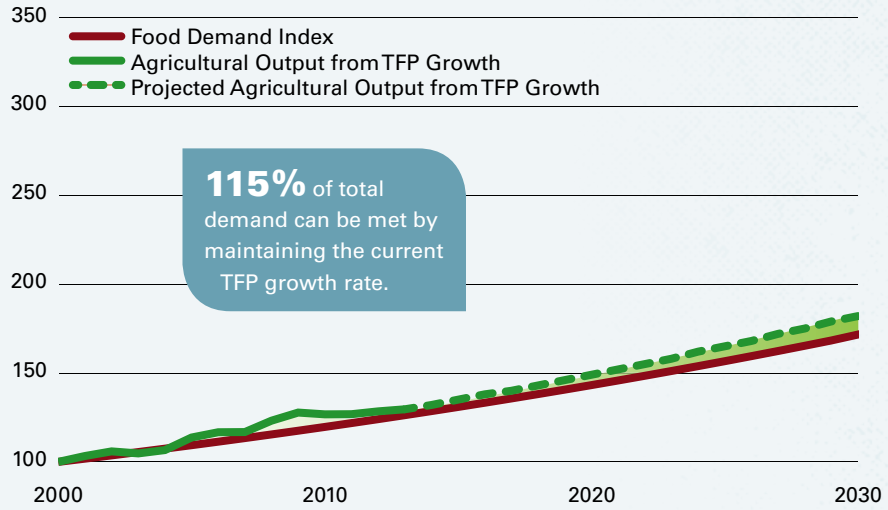
Note on methodology: The projection of agricultural output from TFP growth uses USDA ERS (2016) estimates of average TFP growth during 2004–2013 and assumes this is maintained through 2030. The projected growth in food demand uses UN estimates of population, PricewaterhouseCoopers LLP (PwC) estimates 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.

Figure 6: Food Demand Compared to Agricultural Output from TFP Growth in **Sub-Saharan Africa**, 2000–2030



Source: Food Demand Index is from Global Harvest Initiative (GHI 2016); Agricultural Output from TFP Growth is from USDA Economic Research Service (2016).

Figure 7: Food Demand Compared to Agricultural Output from TFP Growth in **Latin America/Caribbean**, 2000–2030



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

Credit: UN FAO Niger

A BLUEPRINT FOR CLIMATE ACTION IN AGRICULTURE

Agriculture and forestry production are the sources of nearly one quarter of global greenhouse gas (GHG) emissions. The majority of agricultural emissions are from deforestation and land use change (the conversion of forest to croplands or grazing lands), methane produced by livestock and poor soil management. As if the challenge were not already daunting enough, the need to reduce these emissions comes at a time when a rising global middle class is demanding a wider variety of foods and more livestock-based products.

Farmers, ranchers, forest managers and agricultural businesses are in the unique position of being among the most vulnerable to climate change while simultaneously being in the best position to help mitigate it. Agricultural producers are already adjusting to meet this challenge, but more action is urgently needed; solutions applied today will not have a significant mitigating impact until 2040.

The year 2015 was a critical one for international climate negotiations, and culminated in the adoption in December of the **Paris Climate Agreement** at the **COP21 (21st Session of the Conference of Parties)**. Scheduled to enter force in 2020, it strengthens the resolve to limit the global temperature increase to under 2 degrees Celsius.

The Paris Agreement, a blueprint for climate action, was adopted by 188 countries representing 98 percent of the global population and almost 99 percent of all global GHG emissions. Countries have created commitments (Intended Nationally Determined Contributions, or INDCs) for actions they will take to achieve national targets for a low-carbon, climate resilient future. INDCs require regular reporting on emissions and progress made to implement their plans.

While agricultural production is a significant source of emissions, **agriculture itself can also serve as a force to mitigate greenhouse gases**. Focusing on improving agricultural productivity is a vital first step in reducing agriculture's overall environmental and GHG impacts. Certain farming practices and innovative and precision agriculture technologies can mitigate GHG emissions, primarily through improved crop production, cropland and grazing land management, livestock emissions management, restoration of degraded lands and soil carbon sequestration. Other key strategies include improving water and rice management, and crop nutrient and livestock manure management. GHG emissions can also be reduced by substituting fossil fuels with agricultural feedstocks such as biodiesel and biofuels.

AGRICULTURE BECOMES A MITIGATION POWERHOUSE

By adopting mitigation practices and enhancing productivity, the agriculture and forestry industries will be able to reduce net emissions to half of current levels by 2050 while still providing for global food and agriculture needs.*

Cropland technologies and management: Improved crop genetics and conservation practices increase yield and reduce the amount of land required, slowing the conversion of natural habitats to crop production. Biotechnology and genetic modification can improve crops so that they require fewer herbicide and pesticide applications and less energy to fuel the machinery that applies them. Rotating crops with legumes fixes nitrogen to the soil, enables soils to store organic matter and improves soil carbon sequestration. Planting cover crops preserves soil nutrients, improves the soil's water-holding capacity and helps sequester carbon in the soil.

Nutrient management: Nitrogen in fertilizer and manure can be a source of GHG emissions and pollution. When managed properly and used in precision agriculture systems, over-application can be avoided, runoff reduced and emissions minimized.

** Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group 3 of the Fifth Assessment Report of the Inter-Governmental Panel on Climate Change,* (2014).

Tillage management: Reduced or no-till systems prevent erosion, soil degradation and carbon loss. They also reduce the cost of farming and thereby maximize returns on investment for farmers. Improvements in farm machinery, in combination with high yielding, herbicide-tolerant GM crops, make it easier for farmers to adopt tillage management systems.

Water management: Precision irrigation systems ensure efficient use of minimal amounts of water. By applying water exactly when and where it is most needed at variable rates, farmers reduce water use while increasing yields.

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 application with dry instead of wet seasons, draining wet fields during the wet season and improving the genetic quality of the rice cultivars.

Agroforestry: Combining livestock production and food crops on land where timber and trees are grown helps conserve carbon and nutrients in the soil, improves the profitability of tree production, prevents erosion and provides shade for livestock.

Grazing land management and livestock management: Both over-grazed and under-grazed pastures store less carbon than optimally grazed lands. To reduce methane emissions from cattle and sheep, ranchers can improve feeds and forages, use dietary additives to maximize feed protein uptake and reduce the amount of feed required, and use methane inhibitors that can reduce methane emissions by up to 30 percent. Improved genetics and health care practices can also help reduce these emissions while enabling farmers and ranchers to produce more milk and meat per animal.

Manure management: Animal manure produces nitrous oxide and methane, but emissions of these gases can be reduced by storing it in covered tanks and using methane digesters. Methane can also be captured and used as an energy source.

Processing and transportation: Half of agricultural emissions come in the post-production stages, including processing and transportation. GHGs can be reduced by substituting alternative fuels such as biofuels, using fuel efficient vehicles, reducing food waste along the value chain and using better packaging materials.

Rice and cattle farm in Uruguay.
Credit: Neil Palmer, CIAT

THE BUSINESS CASE FOR CLIMATE LEADERSHIP

Climate change has become a leading risk factor for producers and industries along the agricultural value chain. With unpredictable conditions, current business models may become irrelevant, leading to greater market uncertainty. On the other hand, the need to address and mitigate climate change also provides businesses with a new range of opportunities.

As the impacts of climate change unfolds across agricultural regions, a growing number of farmers will need crops that have greater tolerance to heat, drought and require less water. Livestock farmers will need genetically improved breeds and new products such as protease enzymes that reduce livestock emissions and help manage manure.

Innovative agricultural mechanization and precision systems — some in development, others already available on the market — will help farmers apply fertilizers more efficiently and variable rate irrigation will reduce water use. Innovation in weed-control systems enables reductions in tillage and adoption of cover crops that sequesters more carbon in soils. These are only a few examples of the emerging practices, innovations and integrated systems that are transforming agriculture into a climate change mitigation powerhouse.

Private sector investment, innovation and scale will help more farmers, ranchers and forest managers access these tools and contribute to a low-carbon agriculture system.

The value that society places on reducing GHG emissions is leading to consumer demand for climate friendly production methods and supply chains. By voting with their shopping carts, they are sending a message to food retailers, starting a cascade of market signals that reach all the way to the producer level. Consumers are demanding, for example, that food retailers provide information about which foods are the most climate-friendly, and producers and agricultural businesses along the value chain should seize opportunities to collaborate with trusted partners in providing transparent, science-based and verifiable data to support GHG reduction claims.

The following stories demonstrate how **global agribusinesses can contribute to a low-carbon agriculture system** by changing how they operate, reducing the GHG impact of the products they produce, partnering with farmers, conservation organizations and government agencies to improve productivity, water quality and protect wildlife and employing cutting-edge technology to increase livestock productivity while reducing methane emissions.

A CARBON NEUTRAL FUTURE

In December 2015, **Monsanto Company** announced a corporate commitment of becoming carbon neutral by 2021. The company commissioned life-cycle assessment (LCA) studies at both the national level (U.S.) and at the individual field level to better understand which crop-based strategies have the greatest potential to reduce GHG emissions. Many of Monsanto's seed production and farmer customers are planning to implement GHG reducing products (nitrogen stabilizers, soil amendments and advanced germplasm) and practices (precision agriculture systems, variable rate input use, swath control, reduced tillage and cover crop use). Work is underway that will demonstrate the impacts of these practices on productivity, profitability and risk.

To track progress, Monsanto is partnering with academic and third party experts to develop a **scalable and verifiable carbon accounting framework** that offers a transparent system for reporting GHG reductions from use of these products and practices, which will count towards offsetting Monsanto's annual goal. This approach, which is common in the coffee and chocolate industries, has been referred to as **"GHG insetting"** (similar to offsetting except they are generated and retired within the supply chain for row-crop products).

The company has also **established an internal price of carbon** that is factored into its strategic decision-making and investments. Implementing a shadow price on carbon increases the competitiveness of climate-friendly investments relative to more carbon-intensive alternatives.

STEWARDSHIP FOR SUSTAINABLE RICE AND WILDLIFE

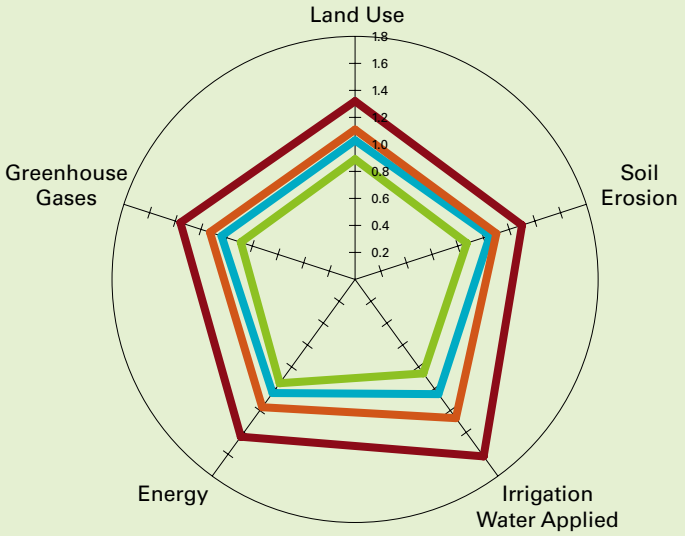
Rice is the world's most widely consumed grain, sustaining approximately half of the global population. Nearly half of the rice produced in the U.S. is exported. With 2.77 million acres under rice production (2015), U.S. rice growers are stewards of wetlands used by North America's waterfowl and 32 other at-risk species. **An environmentally sustainable approach to producing rice not only protects wildlife and the resource base, but also helps achieve global food security.**

As the world's leader in wetlands conservation, **Ducks Unlimited (DU)** counts the rice industry as a key partner in sustaining the future of waterfowl. The compatibility of on-farm conservation practices that improve water quality, farm profitability and wildlife habitat led DU to join forces with **USA Rice** to form the **Rice Stewardship Partnership. The Mosaic Company Foundation** has provided key funding for the partnership's work in the Mississippi Alluvial Valley, where most of the U.S. rice crop is grown.

Working with the **U.S. Natural Resources Conservation Service**, the Rice Stewardship Partnership helps farmers meet the increasing demand for rice while improving environmental performance and farm profitability and preserving wetland resources. Collaborating with leading agricultural, conservation and environmental organizations, the partnership equips rice producers with the support, knowledge, tools and practices to improve farm management and water quality, thereby reducing the level of nutrients lost to the Mississippi River. Mosaic's interest in the program stems from a desire to promote the **4R Nutrient Stewardship framework** *(Right Nutrient Source, Right Rate, Right Time, Right Place)* at the field level to achieve optimal crop uptake of nutrients while minimizing environmental impacts.

There are numerous other environmental benefits of the program. Water use efficiency recommendations, including alternative irrigation strategies, help conserve water and reduce demand on surface and groundwater resources. The partnership promotes practices that minimize energy consumption, reduce diesel fuel use and improve rice crop residue management — all of which translate to reduced GHG emissions and improved air quality. These efforts support the farmer's profitability by maximizing the efficiency of inputs and reducing costs.

Figure 8: Productive, Sustainable Rice: Index of Per Pound Production Resource Impacts, U.S., 1980–2011



Since the 1980s, farmers have produced more rice using less water, energy and land acreage, along with a reduction in soil erosion and greenhouse gas. Rice growers in the U.S. now use the latest in proven irrigation and production practices, saving water and generating carbon emission credits as part of California's carbon cap-and-trade market.

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

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

The Rice Stewardship Partnership delivers conservation and greenhouse gas mitigation practices that improve farmer profitability and meet the global demand for food.

Credit: Mike Checkett

Improving Feed Lowers GHG Impact of Dairy and Poultry

Methane from animal agriculture, particularly emitted from ruminants (cattle and sheep) is a major contributor to greenhouse gas. As demand for dairy products grow worldwide, every effort must be made to reduce the amount of emitted methane per cow while increasing milk output.

Supplements added to feed for livestock can greatly reduce the climate impact of livestock production. **DSM Nutritional Products**, a Dutch company, developed a methane inhibitor product (3-nitrooxypropanol, or 3NOP) and is collaborating with an international team of researchers at **Pennsylvania State University** to test the impact on milk production in dairy cows. 3NOP was added to feed of Holstein cows; milk protein and lactose yields were increased by 3NOP in feed, while **methane emission was reduced by 30 percent** over cows not given the feed additive.[25]

Global demand for poultry is also rising rapidly, along with a growth in demand for feed and nitrogen fertilizers to produce the feed. In the poultry industry, producers are seeking to improve feed so that protein (amino acid) content and uptake is optimized rather than wasted in manure, where it is converted to ammonia nitrate and nitrous oxide, which are potent greenhouse gases. The inefficiency of feeds also costs producers money, as more feed is required per bird.

To help make the poultry value chain more productive for farmers and to reduce the climate impact of manure and feed production, **Novozymes**, the world's largest provider of enzyme technologies, is developing products such as protease enzymes that provide significant nutritional benefits. **Proteases** are added to feed to increase dietary protein uptake by poultry and improve nitrogen utilization in digestion. This in turn leads to less feed required per bird, and the reduction of nitrogen content in their manure. In addition, by requiring less feed, **farmers can reduce production costs and improve profitability**.[26]

With the ability of the private sector to bring improved feed products more widely to scale, livestock production should see a substantial reduction in greenhouse gas emissions, with the added benefit of making feed more effective for livestock consumption, along with improved operational profitability.

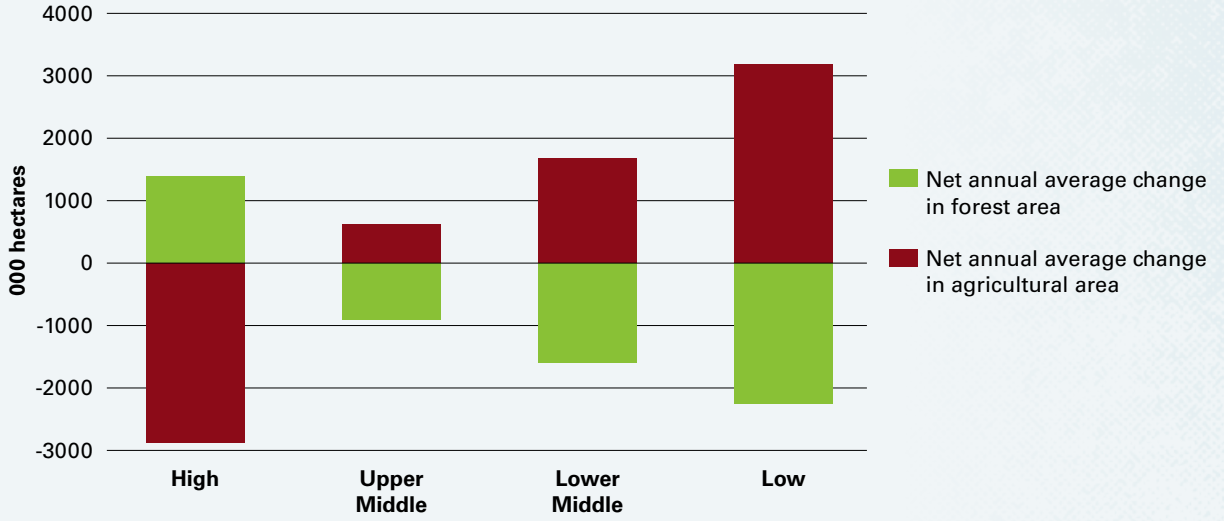
SUSTAINABLE LANDSCAPE MANAGEMENT

Meeting the world's increasing demand for food while reducing the climate impact of agriculture will require highly productive landscapes that are managed sustainably. Forests play key roles in the water cycle, soil conservation, carbon sequestration and habitat protection, including for pollinators. In high-income countries, the overall expansion of agricultural production has slowed significantly, yet global **agriculture remains the most significant driver of deforestation**,[27] and there is an urgent need to promote more positive interactions between agriculture and forestry.

As farmers and ranchers expand into native habitat, they clear forest and convert native habitat (including grasslands) to bring new land under production. Forested areas are on average declining relative to agricultural areas in most countries around the world, with the exception of high-income countries (Figure 9).[28]

Productivity in agriculture, combined with specific strategies to develop sustainable landscapes through improved management and planning, are required to preserve forests and help them retain their carbon storage potential and their ability to help mitigate climate change. The following case studies from Brazil and Indonesia demonstrate how public-private sector partnerships are improving landscape management practices, as well as improving productivity and livelihoods.

Figure 9: Net Annual Average Change in Agricultural and Forest Area, Countries by Income Category, 2000–2010



Source: FAO, 2016.

Note on methodology: The figure covers those countries and territories for which data were available on both agricultural area (FAOSTAT3 website (available at http://faostat3.fao.org) and forest area (FAO, Global forest resources assessment 2015, Rome (available at www.fao.org/forest-resources-assessment/en). Countries with significant inconsistencies in the reported data were excluded from the analyses. The figure uses income categories as defined by the World Bank (http://data.worldbank.org/news/new-country-classifications) and does not take into account changes in income categories over the period 2000–2010.

GROWING MORE, EMITTING LESS WITH GM CROPS

Purdue University research indicates that the land use impact of genetically modified (GM) crop technologies in corn and soybeans has been substantially beneficial. If the rest of the world caught up with the level of GM crops used in the United States, yields would improve and less land area would be planted, reducing global cropland by about 800,000 hectares. **Forests would cover 60,000 more hectares** than today and **pasture for livestock would cover the other 740,000 hectares** currently devoted to crops.[29]

In addition to saving forested land from conversion to cropland, GHG emissions would decline. Conversely, if there was a **total ban on future GM crops globally, 900 million more metric tons of CO2 equivalent would be emitted due to land conversion** required from lower crop yields — equal to burning **960 billion pounds of coal** or consuming **2 billion barrels of oil**.[30]

Compacts for Green Growth in the Amazon

A **Green Growth Compact (GGC)** is a multi-stakeholder arrangement that can be applied in jurisdictions around the world. It brings together producers, government, companies, financial institutions and other influential stakeholders to support alignment of conservation, development, production and social inclusion. The goal is to increase productivity and profitability for small-scale farmers and other value chain actors while protecting natural habitats and increasing carbon storage.

The Nature Conservancy (TNC) has undertaken the GGC approach in **Brazil's Southeastern Pará State**, which is on the front lines of Amazonian deforestation that is being driven by cattle ranching to meet the growing global demand for beef. This is done by working in partnership with farmers, ranchers and food producers, at significant volumes over large landscapes, and providing them with tools, resources and a value proposition to transition to sustainable production. It all takes place within a framework for strong environmental commitments, a clear business case for sustainability, and governance and conservation actions that limit activity on frontier areas that are most sensitive to land use conversion.

The Brazilian Forest Code, which strictly limits deforestation, requires that all private lands are registered in the **Rural Environmental Registry (CAR in Portuguese)**. Registration, along with satellite and other mapping technology, enables the government to link deforestation with actual properties and property owners, creating accountability. Government policies to protect land have frozen further expansion to the west in Pará State; however, deforestation on private lands and pressure on public and indigenous lands remain significant.

São Félix do Xingu, a large municipality in southern Pará, covers 8.4 million hectares (almost the size of Portugal) and has a population of about 107,000 people and the largest cattle herd in Brazil — about 2.2 million head. The area's deforestation rate has been one of the country's highest, driven largely by traditional, low-yield cattle ranching and agriculture.

TNC helped the municipal government register almost 90 percent of its land with CAR, paving the way for information to influence other agencies and companies to implement actions that reduce deforestation in the municipality.

As a result of this and of further government actions such as the **Green Municipalities Program**, the deforestation rate in São Felix has now dropped to about 25,000 hectares per year, a nearly 80 percent reduction from the 1999–2008 average.

Under the GGC approach, these policies have been augmented with incentives and opportunities for low-carbon growth, such as sustainably intensifying cattle ranching and expanding cocoa plantations in degraded areas, that can increase production and rural incomes without clearing forests. To advance these more sustainable systems, TNC is working with retailers such as **Walmart** and **Marfrig** to eliminate deforestation from their beef supply chains and with **Cargill** to expand cocoa production. TNC also works with indigenous peoples in São Félix to support their management of their lands in conformity with Brazil's policy and local community goals.

Going forward, Pará State has launched a process to develop a new economic development plan through 2030 (called **"Pará 2030"**). The plan calls for deeper investment and economic growth across a dozen key industry sectors, including several that have large land-use impacts, such as cattle, agriculture and forestry. At the same time, the Governor of Pará has committed publicly to achieve net zero deforestation by 2020. TNC is bringing the GGC perspective to this plan, engaging deeply with the government on key elements, to be completed in 2016 with implementation beginning thereafter. The approach serves as an exciting model of how key actors can come together to promote economic growth, social inclusion and environmental sustainability in one, mutually supportive agenda.

A farmer rides through the forest behind his farm in São Félix do Xingu. In 2011, the Pará government launched the Green Municipalities Program to reduce deforestation and support sustainable agriculture and ranching, landscape planning and land titling. In 2013, Pará established the Green Value Added Tax formula, in which existing forest area and percentage of CAR registration were added as criteria for allocating tax revenues to municipalities. This additional source of revenue (potentially climbing to $1 million per year for São Félix do Xingu over the next three years) provides further incentives to reduce deforestation.

Credit: © Kevin Arnold

From the Cerrado to Pakpak Bharat: Climate-Friendly Land Use in Action

Many farmers are eager to adopt sustainable and climate-friendly land-use practices, but need help in planning their farm and forest operations. The goal is to grow more productively on existing land, improve soil carbon retention, and manage water resources effectively rather than expanding production to fragile forests or less suitable soils.

Farmers, conservation organizations, governments and private sector agribusiness have been working together in the **Cerrado savanna region of west central Brazil** since 2008 on climate-friendly agriculture and land use practices. The second largest ecosystem in Brazil after the Amazon, the Cerrado grasslands is an area of enormous biodiversity, with more than 10,000 plant and animal species. Since the early 1980s, the Cerrado has begun its transformation into a major agriculture zone, with soy and beef production for local consumption and export.

To protect biodiversity and reduce conversion of important natural Cerrado vegetation to agriculture, **Conservation International (CI)** and **Monsanto** work with local governments, farmers and communities to prevent illegal deforestation, improve crop yields on existing lands and restore critical areas that, under Brazilian law, should not be farmed. This integrated strategy combining conservation and improved agriculture became known as the **"Sustainable Agriculture Landscape"** approach.

By 2013, the partnership helped create four new protected areas totaling 32,000 hectares, piloted innovative technologies to restore 10,000 hectares and initiated an informal dialogue among producers, government and agribusiness to build alignment and consensus around sustainability challenges and opportunities.

The Sustainable Agriculture Landscape approach shows how to protect forests and biodiversity while sustainably intensifying food production. As part of the program, interactive education creates environmental awareness for the next generation.

Credit: Conservation International Indonesia

Eager to expand this approach to other regions with high biodiversity, CI and Monsanto partnered in the **Pakpak Bharat District of North Sumatra, Indonesia**. With emissions from deforestation and land-use change taken into account, Indonesia is the most intensive emitter of greenhouse gases (GHG), most of which come from burning peat, deforestation and degradation from land conversion for crops.[31]

The government of Indonesia has made a bold commitment **to reduce GHG emissions by 41 percent by 2030** in partnership with international assistance programs, while still growing its economy annually by 7 percent.[32]

In Pakpak Bharat, agriculture is a main source of livelihoods, providing 65 percent of the district's GDP from crops such as coffee, maize and citrus. Pakpak Bharat also has significant areas of natural forest that provide farming communities with freshwater as well as fruit, latex and other goods for both commercial and subsistence use. However, agriculture is also one of the leading drivers of deforestation as producers of all sizes are beginning to expand into the edges of large natural forests as they seek fertile land to meet growing local and global demand for food.

The partnership, which commenced in 2013, is working to reconcile this conflict by working with farmers, government and local village leadership to set up training on sustainable farm management practices, facilitate access to farm inputs (such as maize seeds and fertilizer) and enhance environmental awareness among communities and school groups.

Monsanto sponsored and co-founded with CI a program in Pakpak Bharat that provided training to improve maize productivity. **Yield increases range from 30 to 100 percent**. Farmers also saw their expenses reduced by half, supporting an average increase in monthly income of 34 percent. The approach is currently being refined and applied in other areas in Indonesia as well as in Brazil and West Africa.

POLICIES FOR PRODUCTIVE, SUSTAINABLE AGRICULTURAL GROWTH

A productive, sustainable global agricultural system relies on public policies and investments that mitigate and manage the negative impacts of the agricultural business cycle for producers, consumers and the environment, while reducing waste and loss in the value chain and creating opportunities for economic growth and innovation. The Global Harvest Initiative and its partners have identified **five strategic policy goals** essential to stimulating growth and resiliency in the agricultural value chain.

These policy goals will be explored in detail in the following chapters, including examples from around the world of how policies, innovations and partnerships are transforming the business of agriculture and creating better lives and livelihoods for people along the agricultural value chain. A special section on pulses demonstrates how policies and investments interact with one another to increase the consumption and production of a crucial source of nutrients for human, animal and soil health.

Invest in Public Agricultural Research, Development and Extension

Agriculture research and development (R&D) and extension programs are essential public goods and the principal drivers of Total Factor Productivity (TFP). Along with private sector and collaborative research, public R&D in agriculture plays an essential role in fostering agricultural innovation systems. National agricultural research systems can be innovation centers for local and national food security. Innovations, technologies and practices developed through publicly-funded agricultural research help producers around the world remain competitive by increasing the productivity and sustainability of production, reducing loss and waste in the value chain and enabling them to adapt to, and even mitigate, climate change. Consumers of agricultural products benefit from the lower, more stable prices and increased access to safe, nutritious food resulting from these investments.

Embrace, Customize and Disseminate Science-Based and Information Technologies

Science-based and information technologies help producers manage the ever-present risks in agriculture while improving sustainability and competitiveness. Advanced plant breeding through biotechnology, as well as the use of naturally-occurring microbials, enhances drought tolerance and yields, while disease management practices keep livestock healthy and productive. Efficient irrigation and cultivation technologies improve water productivity and reduce labor burdens, particularly for women and small-scale farmers, enabling them to increase their output and profitability. Innovative storage and cold chain technologies ensure that more agricultural products reach markets rather than landfills. Information technology allows farmers to access vital information on market prices, weather, pests and soil health, and precision agriculture and data management tools help producers reduce costs and conserve scarce resources. New bio-innovation is building a bio-economy with broad benefits for the environment and society. Public policies that support the development, customization and dissemination of these technologies to farmers of all scales and the entire value chain are essential to nearly doubling global agricultural output sustainably by 2050.

Enhance Private Sector Involvement in Agriculture and Infrastructure Development

Policies that support and incentivize private sector investment in physical and human infrastructures are crucial to increasing the productivity and sustainability of agriculture. Public-private partnerships to develop road, water, rail and airport infrastructures can open up new markets and reduce transaction costs for producers and retailers. Access to reliable and affordable electricity and internet makes farmers more efficient and competitive, while reducing loss and waste in the value chain. Partnerships between government, industry and communities to develop an educated, healthy and entrepreneurially-minded workforce will stimulate off-farm employment and reduce rural poverty while generating the innovations to ensure that agriculture is productive and sustainable for generations to come.

Cultivate Partnerships for Sustainable Agriculture and Improved Nutrition

In striving to develop their agricultural economies and reduce malnutrition, governments often seek to leverage partnerships with local and international private businesses, nongovernment organizations, foundations, multilateral institutions and development agencies. The increasing demand for resources from traditional donor countries to address the global refugee crises and to prevent famine in places afflicted by prolonged drought is straining development budgets, making collaboration with private sector essential. For this to happen, development assistance programs must move beyond a "project" mentality and embrace integrated, market-driven approaches that generate inclusive benefits for farmers, processors, retailers and consumers, while striving to increase gender equity and improve nutrition. Developing technical and administrative skills of local populations, businesses and institutions sets the stage for successful long-term development.

Foster Capacity for Regional and Global Agricultural Trade

An enabling policy environment for regional and global trade includes transparent policies and consistently enforced laws and regulations, as well as coherent trade rules across countries. Forward-looking, harmonized trade agreements create opportunities to more efficiently move sustainably produced agriculture products to markets that need them, benefitting both the environment and consumers. Since many countries do not have the human or financial capacity to effectively manage regional and global trade opportunities, policies need to focus on building country and regional capacity to facilitate agricultural trade, with an eye toward helping small and medium-scale farmers access larger markets, increase their incomes and expand their businesses. Improvements in trade policies and infrastructure will enable consumers around the world to access a wider variety of foods, as well as staple foods, at competitive prices. And it will help create employment opportunities along the agricultural value chain and in supporting industries.

PULSES:
THE HEARTBEAT OF SUSTAINABLE AGRICULTURE

WHAT ARE **PULSES?**

Pulses are the dried, edible seeds of legume plants and can be used as food, fodder and seed. There are 11 types of pulses, each having many varieties that can be found across 173 countries. Common pulse varieties include dried beans and dried peas (as opposed to green beans and green peas, which are vegetable crops), chickpeas and lentils.

Pulses for Healthy People[33]

Pulses are an accessible and affordable source of plant-based protein and micronutrients, including folate, iron, calcium, B-vitamins, and antioxidants. Pulses score low on the glycemic index and increase satiety, making them ideal for people struggling with diabetes and weight management.

Pulses for Healthy Animals[34]

Pulses can be grown specifically for animal fodder and the crop residue of pulses grown for human consumption also provides nutritious food for the animals.

Pulses for a Healthy Planet[35]

Pulses are an important part of a sustainable cropping system. They fix nitrogen to the soil, reducing the need for water and improving soil health. Many pulse species are drought-tolerant, making them an ideal crop for dryland regions.

2016 INTERNATIONAL YEAR OF PULSES

The 2016 UN International Year of Pulses (IYP 2016) is drawing renewed global enthusiasm and appreciation for a remarkable crop that promotes the health and productivity of humans, animals and the environment.

The global pulse value chain is complex, encompassing millions of small-scale farmers who produce for personal consumption and local markets, as well as large-scale commercial farmers producing for export markets and food companies. **GHI's five policy areas** create an enabling environment for increasing the productivity and sustainability of the pulse value chain in a way that conserves natural resources, helps farmers adapt to climate change and improves livelihoods and nutrition.

R&D AND EXTENSION

Drought tolerant seeds enable me to be productive even during dry seasons. An extension agent showed me how to keep my soils healthy by rotating my pulse and maize crops.

Through online extension programs I learned that pulses enhance the health of my soil, enabling me to use fewer inputs and less water.

TECHNOLOGY

Biofortified lentils give my family access to essential nutrients such as iron and zinc, which keep us healthy. The crop residue is nutritious fodder for my cattle.

I grow locally adapted varieties of pulses that are capable of withstanding pests and bean diseases. Advanced seed genetics combined with new microbial products increase yields and improve uptake of nutrients from the soil.

PRIVATE SECTOR INVOLVEMENT

Thanks to an affordable loan and weather index insurance, I have the confidence to invest in technologies and inputs to increase my pulse production.

Collaboration among pulse growers, the transportation industry and government has improved my access to reliable transportation systems that get my crop to market.

CULTIVATE PARTNERSHIPS

By partnering with my neighbors in a farmer cooperative, I get higher prices for my pulse crop and use the income to pay for nutritious food, school fees and health care.

Thanks to a public-private partnership to educate people about the health benefits of pulses, consumers are demanding more pulse-based foods, increasing the demand for my crop.

TRADE

Regional trade agreements have opened up new market opportunities for me to sell different pulse varieties to neighboring countries.

Accurate and timely information on global pulse prices, regulatory changes, and crop forecasts help me get the best price for my crop and plan effectively for the next growing season.

POLICY 1

Invest in Public Agricultural Research, Development and Extension

Innovations in agriculture, food and energy that produce more while reducing waste and loss and regenerate natural resources are vital to meeting the agriculture and nutrition needs of 2050.

Innovation is about novelty, change and improvement: it is the implementation of better goods and services, production practices or processes.[1] In agriculture and food production, innovation systems typically emerge from public and private agriculture research and development (R&D) and extension programs, as well as from financial policies and regulatory frameworks that provide incentives and support for those who take innovation risks. From farmers to consumers, and in tandem with government and private enterprises (including regulatory bodies and the financial industry), a range of actors are involved in creating demand for innovation and the necessary structures to deliver it.

Public agricultural R&D and extension programs provide essential public goods and are a principal driver of innovation systems and Total Factor Productivity (TFP). Agricultural R&D investments require long gestation periods of more than a decade to realize the full benefits that these investments generate. Yet over time, they pay large dividends, including higher profits for farmers, more abundant food supply at lower cost for consumers, and more opportunities and a higher quality of life in rural communities.

EVERY PUBLIC DOLLAR invested in agricultural research in the U.S. provides at least $10 in economic benefits to society.[2]

Countries that build national agricultural research systems (NARS) capable of producing a steady stream of innovations suitable for local farming systems have generally achieved higher growth rates in agricultural TFP than countries that do not make these investments.

Low-income countries in particular must prioritize and increase investments, as their R&D spending remains much lower than others as a percentage of their agricultural GDP, a common measure of the commitment to productivity and agricultural innovation. Higher-income countries must maintain a commitment to ongoing agricultural R&D to keep pace with ever-evolving challenges faced by their producers and consumers.

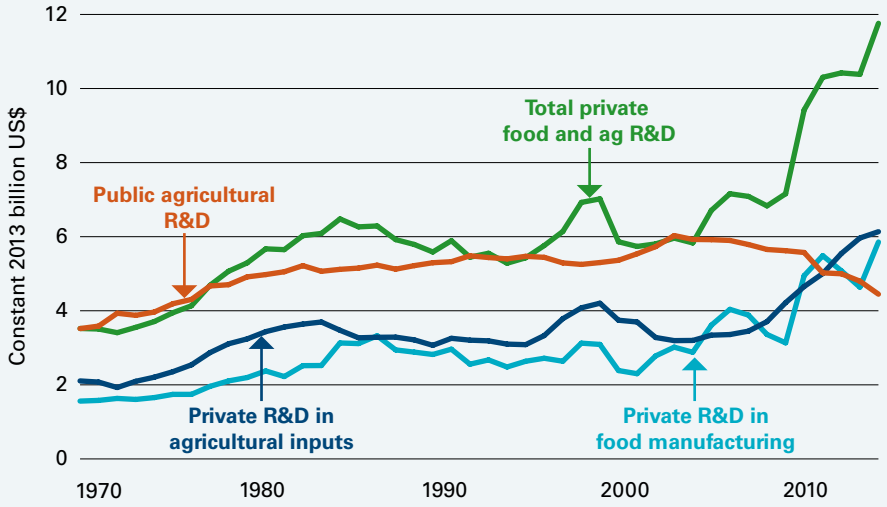
TRENDS IN AGRICULTURAL R&D INVESTMENTS

Since agriculture historically has been comprised of smaller-scale farm operations, the public sector has long been the primary source of agricultural R&D. The United States launched its food and agriculture research efforts in the last half of the nineteenth century, first by investing in the basic and higher education of the general population, as well as those in the agricultural economy. The Morrill Act of 1862 established a system of land-grant colleges and universities that was augmented in 1890 by the addition of historically black universities and colleges. Today more than 100 land-grant institutions across the country conduct agricultural education, research and extension, continually updating science and technology and sharing critical information with farmers, ranchers and the public at large.

U.S. federally funded national research programs continue to focus on basic issues of national level importance related to crop and livestock production and protection, human nutrition and food safety, rural development and natural resource management and conservation. Federal research addresses higher risk and long-term issues, such as unlocking plant and animal genomes, as well as basic research not addressed by the private sector.

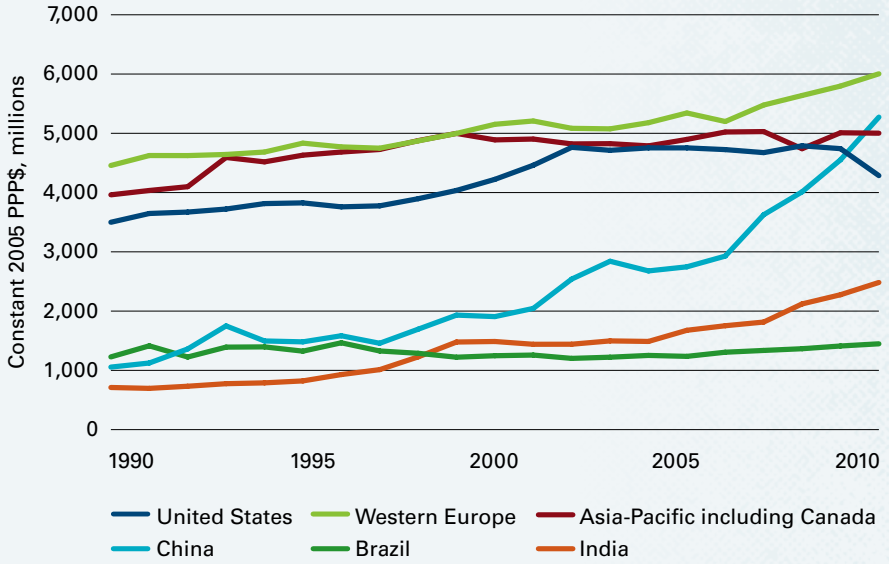
In addition to the government's own agricultural R&D programs, the U.S. also funds external research in partnership with land-grant and other universities at the state and local level that is focused on regional or local needs in environment, human health and agriculture systems.

Figure 1.1: Agricultural Research Funding in the U.S. Public and Private Sectors, 1970–2012



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 using an index for agricultural research spending developed by ERS.

Figure 1.2: National Agricultural Research & Development (R&D) Expenditures: 1990–2010



Source: OECD. 2016. Innovation, Agricultural Productivity and Sustainability in the United States. TAD/CA/APM/WP(2016)15/REV1. Organisation for Economic Cooperation and Development (OECD), Paris, France.

U.S. public agricultural R&D expenditures grew at least 2.6 percent annually in real terms in the years following World War II and this growth continued at a strong pace until levelling off in the early 1980s. **In 2000, the rate of growth in public investment began to slacken, and it has declined 6 percent since then**.[3]

Overall, public funding of agriculture research has generated strong TFP growth rates in the United States, and has also benefitted global agriculture by disseminating improved knowledge and technology, conservation practices and higher profitability for producers.

Meanwhile, private sources of funding for R&D in agriculture production and food manufacturing picked up pace after 2000 (Figure 1.1).[4] However, **research by the private sector does not replace basic foundational research by the public sector**; rather, it focuses primarily on taking results from public sector research to the next level and creating marketable products for growers and consumers. While private sector funding has increased in recent years, **it is subject to greater volatility** and may fluctuate during the more challenging stages in agricultural business cycles when it may be needed most.

Trends for agricultural R&D expenditures among selected countries can be observed in Figure 1.2.[5] China and India have boosted their commitments in the past decade to research, while expenditures in Brazil and countries in Western Europe have plateaued. Given its long history as a leading investor in agricultural R&D, and particularly in light of the many challenges faced by U.S. farmers, fishers and ranchers as well as consumers, the U.S. government must now recommit its support and increase its investments in this critical area.

Understanding and mitigating the impact of climate change, preventing livestock diseases, improving water access and water quality, fighting pests in the crop, horticulture and forest industries, and promoting food safety and good nutrition will all require that the **U.S. invest more in agricultural R&D and sustain those higher funding levels over the next 30 years** to meet the challenge of ensuring global food security through 2050.

"Canola is a versatile and hardy crop--we grow it in a rotation with oats, wheat, flax and pulses and lentils. Canola contains omega-3 and omega-6 fatty acids, is high oleic and free of cholesterol, has a light taste and is very healthy. Our genetically modified canola is resistant to herbicides, and it helps us adopt sustainable practices like no-till, which protects topsoil from erosion and stores carbon. It also enables us to plow less often, saving fuel and equipment use." Lesley Kelly and her son in their canola field, Saskatchewan, Canada.

CANADA'S OTHER OIL: CANOLA FOR THE WORLD

Canola is an oilseed plant that grows across much of Canada. Over the past half-century it has been transformed from a little-known crop used for lubricant properties during World War II to the country's most profitable crop and the third largest edible oil crop in the world. Public and private research collaboration, farmer ingenuity and dedication, along with a suitable innovation-enabling policy environment, are responsible for this dramatic transformation benefiting farmers, rural communities and consumers both in Canada and worldwide.

In the 1950s, Canadian government researchers identified an opportunity to develop a new oilseed based on the rapeseed plant that could complement wheat in the prairies and meet a growing demand for domestic edible oils.

Plant breeders, mindful of consumer and scientific concerns about potentially unhealthy levels of erucic acid in rapeseed, instituted a research program to improve the plant for human and livestock consumption. Canada's agriculture research institute was the only entity willing to fund basic rapeseed research, and genetic germplasm information moved freely between researchers and farmers and other breeders, who worked collectively towards improving the traits and productivity of the plant.

In the late 1960s, an association of groups that had a stake in the emerging rapeseed industry joined together to fund marketing and research to further develop the potential of rapeseed. When plant breeders produced highly desirable varieties containing low levels of erucic acid and glucosinolates, another unhealthy substance in the plant, a new era began in which the name "canola" was trademarked, indicating the healthy variety with guaranteed high standards. Canola was now positioned to become the premium oil for human consumption and marketing efforts were established by the Canola Council of Canada to promote acceptance and grow the market for the oil.

By 1985, several private sector companies such as **Monsanto** began breeding research to further improve the yields and properties of canola. The Canadian government facilitated private sector research efforts by extending intellectual property rights and creating clear, responsible regulations for industry to operate within.

Between 1995–2009, genetically modified, herbicide-tolerant canola in Canada saved

1.1 MILLION
TONS OF C02

emissions, equivalent to removing 500,000 cars from the roads.[7]

Today, the canola industry in Canada has benefitted from private research by Monsanto and other companies that developed conventional and genetically modified (GM) varieties of herbicide-tolerant canola, introduced in 1996. Herbicide-tolerant canola systems are especially beneficial for farmers and the environment, as canola can be grown in a no- or minimum-tillage system of production. Such systems require fewer applications of pesticide and herbicide, make weed control easier, reduce the wear and tear on farm machinery, decrease labor and fuel used, and help sequester carbon in soil and improves soil health. Herbicide tolerant canola generated net total benefits (direct and indirect benefits) of between 1 billion and 1.2 billion Canadian dollars for the period 2005 to 2007, due to lower input costs and better weed control.[6]

While genetic modification in breeding creates a GM canola plant, the oil of such herbicide-resistant varieties is identical to the oil of conventional canola — the oil itself contains no GM material. On the nutrition side, the benefits to consumers continue to grow, as private sector companies are breeding canola to produce healthy omega-3 fatty acids found in fish: DHA and EPA.

A NEED TO BOOST AGRICULTURAL R&D

After the food price crisis of 2007 and 2008, many countries renewed their commitments to put agriculture, and particularly agricultural R&D, at the center of their policy agendas.

In Africa, the **African Union's New Partnership for Africa's Development (NEPAD)** and the **United Nations (UN)** encourage governments to **allocate at least 1 percent of agricultural gross domestic product (AgGDP) to public agricultural R&D**. Nonetheless, overall investment levels in most countries are still well below those required to sustain agricultural R&D needs. In 2011, Africa invested on average just 0.51 percent of agricultural output on agricultural R&D, well below the recommended level. Of the 38 countries for which data were available, 32 still fall short of the minimum investment target of 1 percent of AgGDP.[8]

In many African nations, NARS are highly dependent on funding from donors and development banks — funding that has been less predictable during the past decade. These countries must now mobilize new sources of funding to fill the research investment gap and build NARS and extension systems to boost productivity in agriculture. Countries such as **Tanzania** have formed partnerships with agribusiness and universities to close the R&D gap and build more sustainable and productive agriculture systems.

Investing in Human Capital and Higher Education: A Force Multiplier

As lower-income countries build their national agricultural research systems, **a critical gap to fill** is that of their **human capital through investments in primary, secondary and higher education.** As economies become increasingly knowledge-dependent, the role of higher education institutions becomes even more important.[9] Supporting research capacity within universities helps to increase the resources devoted to R&D, keeps curriculum current and produces higher quality students who are more capable of solving national development problems.

It has been shown that it takes about the same level of economic and technical skills to become an efficient borrower of technology as it does to develop new technology.[10] Therefore, higher education not only helps lower-income countries produce new technology, but also helps adapt technology from other places effectively. **Building higher education capacity is a force multiplier for the necessary human capital to interact with and capitalize on global knowledge flows**.

The returns from higher education are substantial. Contrary to prevailing thought, the poorer the region the greater the return on investment from higher education.[11] In fact, the poorest world region, Sub-Saharan Africa, shows the highest rates of return from investments in higher education at 21.9 percent. This is nearly double that for primary and secondary education in the region, and nearly double the return on higher education for high-income economies at 11 percent.[12]

Closing the Agricultural R&D Gap in Tanzania

In Tanzania, the share of agricultural GDP devoted to agricultural research was 0.54 percent in 2011,[13] just half of the 1 percent target recommended by the African Union. Funded by USAID under the **Feed the Future Initiative**, the **Innovative Agricultural Research Initiative (iAGRI)** is assisting Tanzania in its efforts to close the gap between its actual and targeted levels of agricultural R&D. iAGRI is led by **The Ohio State University** in conjunction with five U.S. land grant universities and the **Regional Universities Forum for Capacity Building in Agriculture (RUFORUM)**.

iAGRI's goal is to assist **Sokoine University of Agriculture (SUA)** and the research institutes of the **Tanzania Ministry of Agriculture, Livestock and Fisheries (MALF)** in advancing their capacity to respond to client needs in the rapidly expanding agricultural markets of the country and the East Africa region.

iAGRI has granted scholarships to 137 Tanzanians pursuing graduate degrees in the agricultural sciences at universities in the U.S., Africa and India. In addition to funding for coursework and research, students are provided with dual advisors from their host university and from Tanzania, as well as leadership training, specialized seminars and laboratory opportunities. The students' research covers a wide range of disciplines, including agricultural economics, agronomy, soil science, plant protection, engineering, nutrition and extension education.

Women's empowerment in leadership and research is a major area of emphasis in the training and institutional capacity building components of iAGRI. At SUA, only 20 percent of academic staff and 30 percent of the students are female. To close this gender gap, iAGRI has awarded 50 percent of its long-term training scholarships to women. iAGRI also provides training and

iAGRI student leads focus group discussion with vegetable traders in Changarawe, Tanzania.

Credit: Winfrida Mayilla

mentorship to increase the acceptance of women in management and leadership positions.

iAGRI also supports inter-disciplinary collaborative research between U.S. and Tanzanian institutions including SUA, the Tanzanian Ministry of Agriculture, Livestock and Fisheries, and the six universities in the Ohio State University Consortium.[14] Examples include farmer training in horticultural techniques such as tomato grafting and improved pest management to increase yields and incomes of small-scale farmers. Conservation agriculture and irrigation techniques have been tested, locally adapted and introduced to farmers to address the effects of climate change.

In addition to increasing its collaboration with the global research community, SUA is shifting its internal structure and training modules to better meet the skill, technology and information needs of the commercial agricultural and agribusiness sectors. Together with **John Deere**, the university has launched a **Tractor Training and Research Program** on the SUA campus to provide an ongoing series of short training courses on tractor operation, tractor maintenance and repair, and tractor business management for farmers, faculty and students. SUA has also launched a university-owned private company to engage in joint ventures with private investors and to manage the university's farm and other income-generating assets.

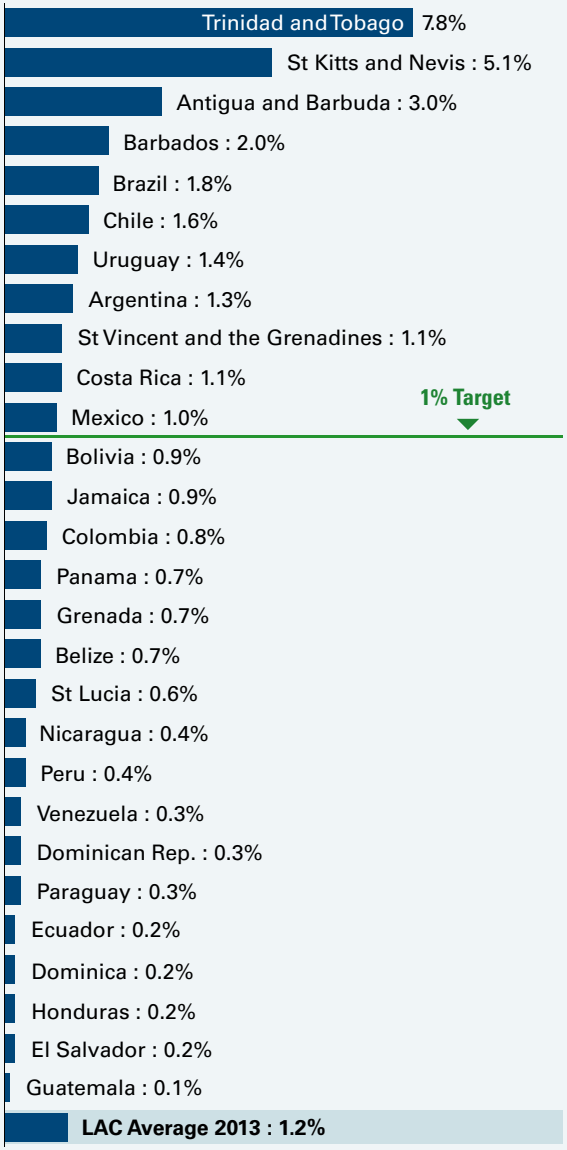
As of 2016, 92 percent of iAGRI graduates are employed, the majority in the agricultural ministry and public universities. They are assuming leadership roles in agricultural research projects, serving as university or institute lecturers in the agricultural and nutrition sciences, working as technicians and serving as advisors. Graduates supported by iAGRI form a unique community of scholars, each equipped with a multi-faceted, well-rounded skillset in the agricultural sciences. Their impact on the agricultural sciences in Tanzania will continue to contribute to food security and nutrition outcomes for years to come.

Latin America and Caribbean Countries Forge Ahead

Countries throughout Latin America and the Caribbean are increasing their investments in agricultural R&D, enabling them to forge ahead to become regional and global suppliers of more sustainable, safe and nutritious food through more productive agri-food systems. On average, the region has met the recommended target of allocating at least 1 percent of agricultural gross domestic product (AgGDP) to research and development, spending $1.15 for every $100 of agricultural output (Figure 1.3). Many countries in the region have exceeded the target, and others are nearing the target by increasing their investments over time.

For additional data on country and regional investments in agricultural R&D, see Agricultural Science and Technology Indicators (ASTI) at www.asti.cgiar.org.

Figure 1.3: Agricultural R&D Spending as Share of AgGDP (%)



Sources: Constructed with ASTI data, and data on AgGDP from World Bank (2016).

FROM THE DRYLANDS OF INDIA TO AFRICA: COLLABORATIVE RESEARCH FOR IMPROVED SORGHUM AND MILLET

The FAO estimates that 55 percent of the world's arid and semi-arid drylands with rainfed farming potential are located in Sub-Saharan Africa and South Asia, particularly India, and these areas also are characterized by populations with the lowest nutrition levels and highest population growth rates.[15]

Sorghum and millets are annual grasses that produce small seeded grains and that thrive in the drylands of India and Africa. These hardy crops are resistant to drought, require short growing seasons (three to four months from planting to harvest), and are used for human consumption or for animal forage and feeds. For millions of the poorest people in the world, sorghum and millets provide the main source of energy and nutrients. Research to improve the nutritional quality and productivity of these crops can dramatically impact the welfare and health of these farmers who produce, consume and market the crops.

In India, research and development to improve sorghum and millets has resulted in highly improved seeds and seed systems for delivering value to growers and consumers. Beginning in 1960s post-independence India, the government led the efforts with public research programs such as the **Indian Agricultural Research Institute (IARI)**, the **National Dry Land Research Center** and the **Directorate of Sorghum and Millet Research**, among others. By 1972, **ICRISAT** (International Crops Research Institute for the Semi-Arid Tropics, part of the Consultative Group for International Agricultural Research, or CGIAR research system) was established, and joined in the collaborative effort with Indian public research centers to conduct research, collect and conserve germplasm and test new hybrid varieties to improve the seed qualities. These early efforts by the public and international research sectors were rewarded with higher yielding hybrids that improved productivity, paving the way for the next phase of development.

In 1971, India's seed sector was deregulated and allowed the entry of foreign firms to conduct research and develop new lines of improved seeds. With a very large market of farmers who adopted improved seed after several growing seasons, India attracted private companies such as **Pioneer** to begin millet and sorghum breeding programs, producing new cultivars with higher yields and properties such as drought and heat tolerance. In 1988, a new seed policy further spurred additional growth in private sector seed research in India.[16] Firms were now allowed to multiply and sell seeds to farmers with less regulatory interference, avoiding lengthy application and approval processes.

ICRISAT's consortium leadership enabled private sector companies, the government and small and medium-sized domestic Indian firms to collaborate on improving seeds and seed markets and extension of new products and training to farmers. In addition, in Western Rajasthan, a dryland zone, ICRISAT started a 10-year research program of farmers' participatory breeding to improve pearl millet and its ability to withstand drought. The new and improved varieties resulting from this collaborative research program resulted in higher incomes for the farmers, with higher rates of school enrollment for their children, especially among girls, and improved homes and assets, all made possible with the higher incomes from the improved productivity of millet.[17]

Recent initiatives have included a new ICRISAT-led informal consortium that has come together to sequence the pearl millet genome.

Pearl millet field in India.
Credit: ICRISAT

Additional initiatives are focused on **improving the nutritional quality of pearl millet and sorghum**. Pioneer's hybrid pearl millet product has one of the highest levels of iron and zinc density and can be used for expanding cultivation throughout India to address anemia and zinc deficiency malnutrition.

Despite the documented productivity of these crops under challenging conditions, the full potential of sorghum and millet is yet to be fully achieved in Africa, particularly in more vulnerable areas of the Sahel and dryland cropping areas. Building on the powerful public and private research experience with sorghum and millet in India, the **Agropolis Foundation, DuPont Pioneer** and other partners in Africa are building a new initiative focused on improving sorghum and millet productivity in Africa, where these crops have been on the decline for 20 years. New innovative partnerships will catalyze productivity and competitiveness of sorghum and millet value chains by improving seed systems and seed product development, and connecting smallholder farmers to markets.

EXTENDING KNOWLEDGE AND INNOVATING TOGETHER

Agricultural extension systems provide the link between public research and farmers, enabling them to quickly and easily understand and adopt innovation to benefit their business operations, the natural resources they manage, their families and the communities they live in.

The U.S. cooperative extension program was established by the Smith-Lever Act in 1914 and has become a model for many other countries. Working cooperatively, the federal government agencies involved in agricultural research, along with land-grant universities across the country and local county governments, built a solid structure for producing and sharing results and new practices.

These extension systems serve to keep farmers successfully involved in agriculture, providing advice, training, and support for rural entrepreneurship. A recent study demonstrated that **since 1985, some 137,000 farmers would have left farming without the specific services of cooperative extension**.[18]

Initially, extension systems were established in the U.S. as a top-down model in which new information, practices and technologies flowed from experts to farmers. With a decline in the matching state-level investments for extension after 2007 due to the recession, and with a growing trust gap between some producers and science and educational institutions, challenges to this model require a fresh, interactive model of partnership for knowledge exchange.[19]

Farmers' social networks — trusted people in their home, community and business circles — play key roles in helping farmers adopt new information, practices and technologies. When it comes to helping farmers of all sizes and operations adapt to climate change, trusted sources of information combined with practical tools are needed to understand the impacts and opportunities to build resilience at the farm level. Cooperative extension is critical to helping farmers prepare their operations to reduce risk from weather impacts and climate change. Farmers also learn from private sector farm chemical dealers, seed dealers and certified crop advisors (CCAs).

"In a healthy system, research and extension work together with agriculture to drive innovation and foster adaptation to change. Useful to Usable provides farmers with innovative tools that help improve their farm decision making."

~ Professor Linda S. Prokopy, Useful to Usable Lead Project Director, Purdue University

Cooperative extension agents can engage with social networks and can develop tools for farmers that help them adapt to climate change and implement conservation agriculture practices. For example, **Purdue University** launched the **Useful to Usable** initiative, a regional level, multi-institutional program offering a suite of online tools to help farmers and agricultural advisors manage the increasingly variable weather and climate conditions across much of the Midwest Corn Belt. Farmers can get online access to historical climate data and many other data sources for production and marketing decision-making throughout the growing season, essentially helping farmers climate-prepare their operations.

International Extension Shifts into Gear

Agricultural R&D and extension systems in many lower-income countries have not been a priority due to budget constraints and the lack of prioritization. But new approaches and models to extension are emerging and as countries build out their research and extension systems, greater participatory models are evolving to fill the extension gap.

Working with international development institutions such as the **U.S. Agency for International Development (USAID)**, the private sector and non-governmental organizations, novel approaches to sharing technology and practices are being tested. Examples from the **Democratic Republic of Georgia** and from **Kenya** offer successful models of how to ensure farmers of all scales can become users of new technology and innovation to build thriving businesses and supply food more sustainably.

Linking Farmers to Solutions in the Republic of Georgia

In 2014, the European Union removed the import duties from qualified agricultural goods produced in the Democratic Republic of Georgia, giving the country's farmers duty-free access to one of the wealthiest markets in the world.[20] But decades of underinvestment have left Georgia's farmers ill-equipped and unprepared to take advantage of this new market opportunity. In addition, poor agronomic practices and changing climate patterns have degraded 35 percent of the agricultural land, with nearly 3 million hectares of arable land lost to soil and wind erosion.[21]

At a time when many countries are looking to the private sector and NGO communities to supplement their meager extension systems, Georgia is committed to developing a robust, innovative public sector extension system that is farmer-driven and pulls from a wide spectrum of experts and resources.

The **Georgia Ministry of Agriculture (MOA)** has more than doubled its annual budget and a significant portion of the new investment is for the public extension and advisory services (EAS) system. Through the USAID-funded **Strengthening Extension and Advisory Services in Georgia (SEAS)** initiative, a three-year partnership (2013–2016) between the MOA, the **Modernizing Extension and Advisory Services Program at the University of Illinois at Urbana-Champaign** and **Winrock International**, Georgia is linking producers with the information and technologies they need to improve their productivity and business operations.

Georgia's extension and advisory services help improve orchard management and productivity.

Credit: Givi Pirtskhalava / World Bank

SEAS (pronounced "say-as") helped build capacity for Georgia's EAS, working with MOA officials to develop agricultural extension policies and build an organizational structure to support a farmer-focused partnership-driven extension system.[22] In order to reach more farmers more efficiently, the SEAS team created videos on best-practices for orchard and vineyard management, soil nutrition and testing and vegetable grafting that were broadcast by the Georgian Association of Regional Broadcasters.[23] Extension experts from six universities in the U.S. and Israel came to Georgia to "train the trainers", providing extension agents with the latest technical knowledge and improving their outreach skills. The SEAS initiative ended in 2016, but multilateral donors and development agencies are stepping in to ensure that Georgia's EAS system will continue to expand and thrive.

Mobile Units Extend the Science and Business of Farming

Accessing education and new agricultural innovation can be challenging for small-scale farmers who have limited connection to formal institutions and extension systems as they seek to improve the productivity and sustainability of their farms.

A partnership between **John Deere Foundation** and **Technoserve** (an international development organization) is helping farmers in Kenya and Ghana learn the business and science of farming. The **Mobile Training Unit (MTU) program** uses video technology to bring agronomic information to farmers in remote communities that have limited access to extension services. The project combines agricultural and business training in several important value chains: dairy, horticulture and maize in Kenya and rice, sorghum, maize, cowpeas and soy in Ghana.

The MTU is comprised of a large truck fitted with an LED screen and speakers, a tent and chairs for up to 400 people. Farmers gather to watch specifically tailored videos designed to improve their knowledge of improving soil health, planting, irrigation, tillage, post-harvest storage, and marketing.

Credit: Technoserve

To reinforce the video presentations, Technoserve establishes demonstration plots where farmers receive continuing education in applying agronomic best practices. At the same time, the project staff works to build the capacity of financial institutions and input dealers to meet the needs of small-scale farmers, while creating linkages between the farmers and agricultural processors.

Launched in 2013, the project's first phase reached roughly 20,000 farmers, surpassing its target by more than 40 percent, with an impressive 65 percent of farmers adopting some of the practices they learned through the MTU. By 2015, approximately 33,000 farmers had benefited from the MTU program, increasing their yields and generating up to $15.5 million in incremental revenue.

POLICY 2

Embrace, Customize and Disseminate Science-based and Information Technologies

Science-based and information technologies help producers manage the ever-present risks they face in agriculture while improving their productivity and competitiveness and delivering wider social and economic benefits.

Biotechnologies protect crops against stress such as drought and pests, helping farmers guard against yield losses. Genetic improvements and disease management keep livestock healthy and productive. Efficient irrigation and cultivation technologies improve water productivity and reduce labor burdens, particularly for women and small-scale farmers, enabling them to increase their output and profitability in sustainable ways. Innovative storage and cold chain technologies ensure that more agricultural products reach markets and not landfills.

Information technologies allow farmers to access vital information on market prices, weather, pests and soil health, and traceability for food safety and consumer information purposes. Precision agriculture and data management tools help producers reduce costs and conserve scarce resources such as soil, crop nutrients and water. Bio-innovation in agriculture is helping build a bio-economy with broad benefits for the environment and society.

As a matter of public policy and business practice, technologies that have benefited larger-scale agriculture systems in higher income countries must be customized for new users, particularly small and medium enterprises in lower-income countries. Access to technological advancements is particularly important to improve farming and agribusiness in low-income countries, where opportunities to meet local and regional food demand are expanding and where agriculture employs high percentages of the workforce and accounts for, on average, nearly 30 percent of the GDP.[1]

Public policies that support the development, customization and dissemination of these technologies to farmers of all scales, and to other actors along the value chain, are essential for nearly doubling global agricultural output sustainably by 2050. While public and private agricultural R&D investments help spark innovation, **effective regulatory systems** enable these innovations to be enhanced and shared more widely by the private sector and farmers and embraced by consumers, building confidence in their benefits as well as providing opportunities to add value.

SMART REGULATORY SYSTEMS THAT BUILD TRUST AND COMPETITIVENESS

Governments establish agricultural policies and regulations to ensure human health and safety, protect the environment and animal welfare, and foster economic growth while meeting consumer needs for food, fiber, fuel and other coproducts. **Smart regulatory systems that keep pace with rapidly changing innovations in science and technology can foster the adoption of such innovations.**

A successful regulatory system establishes predictable, clear, science-based operating conditions for farmers and ranchers — particularly with regard to seeds, crop protection and animal health — as well as for mechanization companies, insurance and finance firms, and food processing and retail industries, so that the overall agriculture sector can deliver value for people, the environment and the national economy.

In today's global competitive environment, regulatory systems are being called upon to do even more, as consumers seek more information about production methods, nutritional content, labor practices and sustainability of local, national and international food and agriculture systems. Transparency and traceability are growing in importance for developing consumer trust, while affordability and accessibility remains a paramount concern for many customers.

During challenging phases in agricultural business cycles, it is especially important that government regulatory systems help foster productivity and innovation while avoiding unnecessary costs, delays and burdens to the agriculture sector, ultimately impacting the ability to swiftly deliver quality products to consumers. Regulatory systems should have a sound legal and empirical basis, minimize costs

and market distortions and promote innovation through intellectual property protection and market incentives. They must be clear and practical for users, and be compatible with domestic and international trade principles.[2]

Smart regulatory systems contribute to innovation and productivity when all the participants — government, industry, producers, scientific researchers, members of the media and consumers — responsibly engage in practice as well as understanding about new opportunities that science and technology bring. Ideally, farmers practice good stewardship with innovation technology; input providers, processors and retailers work within regulatory frameworks; government consults with all relevant parties and establishes well-functioning, science-based and clear regulatory practices; media responsibly explain agricultural policies, innovations and practices in a fact-based manner; and consumers have easy access to facts to make informed decisions.

Smart, Science-based Regulatory Systems

Promote Innovation, Entrepreneurship and Competitiveness

- Establish property rights, especially land ownership, and provide for flexible land tenure and access for producers;
- Provide fair intellectual property (IP) protection;
- Allow ease of business startups while preventing monopolies or collusion;
- Encourage market demand to guide production decisions; and
- Seek stakeholder input throughout the regulatory system.

Protect Natural Resources and Environment

- Prevent adverse effects on the environment, particularly from crop protection products and concentrated livestock production;
- Promote and incentivize good stewardship of soil, forest and water resources; and
- Implement science-based animal welfare and care standards.

Ensure Consumer Health & Safety and Build Trust

- Reduce risk from pests and disease to the food supply and to human health through inspection programs;
- Manage biotechnology innovation through streamlined and coordinated, science-based biosafety frameworks;
- Ensure animal health products are used judiciously for optimum benefits;
- Establish and enforce labeling standards that inform consumers about nutrition and safety issues in food;
- Use data and information technology for traceability and quality assurance to consumers; and
- Set high standards to prevent bad actors from marketplace entry.

SHARED RESPONSIBILITIES

Farmers practice good stewardship

Input Suppliers, Processors and Retailers work within regulatory frameworks

Government consults with all parties to establish well-functioning science-based, clear regulatory practices

Media responsibly explain agricultural policies, innovations and practices in a fact-based manner

Consumers seek factual information to make informed decisions

FORWARD WITH BIOTECHNOLOGY

The United Nations Food and Agriculture Organization (FAO) recognizes that the rapidly emerging, broad-based field of agricultural biotechnology can complement traditional agricultural approaches to sustainably increase farm productivity, especially for small-scale farmers. These farmers provide up to 80 percent of the food supply in Asia and Sub-Saharan Africa. Across low- and middle-income countries, there is a need to help the millions of small-scale and emerging farmers, particularly women, with improved technologies and practices that can reduce their labor burden and improve their farm profitability and productivity.

Ensuring that more farmers access and use improved biotechnology is a vital step towards ensuring they can grow their agricultural businesses, improve their incomes and nutritional status, as well as that of their families, all while conserving the natural resource base.

To this end, FAO hosted a neutral, open forum in February, 2016, "The Role of Agricultural Biotechnologies in Sustainable Food Systems and Nutrition," that was attended by nearly 500 participants. Farmers from Asia, Africa, North and South America and Europe shared their experiences using a broad range of agricultural biotechnologies to grow food. Joining them were scientists, policymakers, civil society organizations and agriculture industry participants.

AGRICULTURAL BIOTECHNOLOGY

is a range of tools, including traditional breeding techniques and genetic engineering, that alter living organisms, or parts of organisms, to make or modify products, improve plants or animals, or develop microorganisms for specific agricultural uses.[3]

Participants discussed current and emerging biotechnologies such as improved tissue culture in plants and new vaccine technologies in livestock. Use of molecular markers and genetic modification for crops are all valid ways of boosting resilience to climate change, disease and drought. Biotechnologies are also used to fortify the nutritional content of staple food crops like rice and sorghum, making more vitamin A, zinc and iron available in the food that 300 million resource-poor consumers eat every day across dryland zones of Africa and India. Other biotech benefits include improving the shelf life of agriculture products, thereby reducing food loss and waste, as well as harnessing natural microbes to reduce methane emissions from livestock.

Scholarly research conducted over the past 20 years has shown how biotechnology in general and genetically modified (GM) crops in particular have benefitted farmers of various scales.[4] GM crops have been one of the fastest technologies to be adopted in recent history, moving from large-scale commercial farmers in the Americas and more recently to farmers of all scales in Asia.

Most promising is that biotechnology, including genetic modification and genetic engineering (GE), has great potential to help small-scale farmers in developing countries produce more food per hectare, even in areas where drought, pests and floods have been continual challenges.

On average, GM technology adoption has reduced chemical pesticide use by 37 percent, increased crop yields by 22 percent and increased farmer profits by 68 percent, with yield and profit gains higher in low-income countries than in high-income countries.[5]

When smart regulatory and biosafety systems are in place along with stewardship training for farmers, national governments can forge more sustainable agricultural systems. The importance of consumer acceptability of new products and the need for communication and dialogue, from an early stage and with multiple stakeholders, is paramount to achieve acceptance.

FAO Director-General Jose Graziano da Silva addresses the biotechnology symposium. The willingness to listen and to bridge the "trust gap" between all parts of the agriculture and food value chain — and across different methods of production — will help realize the promise of agricultural biotechnologies for farmers, consumers and the natural resource base.

Credit: ©FAO/Giuseppe Carotenuto Copyright ©FAO.

Blocking Innovation, Stalling Progress

Inefficient government regulations erect barriers to market entry for new seed traits, with project costs now averaging $136 million over 13 years for a single new trait.[6] Misinformation campaigns against genetic modification in agriculture are blocking the development and adoption of new crop varieties that could provide important benefits for smallholder farmers in Africa.

Estimates are that the current restrictive climate for biotech innovation in agriculture **will cost low- and middle-income countries up to $1.5 trillion in foregone economic benefits through 2050**.[7] These restrictions lower farmer productivity and raise food prices. Such campaigns prevent or threaten to limit exports to Europe from African countries, as well as use informal pressure to adopt highly restrictive biosafety regulations that limit the use of productive GM seeds.

Biotechnology for Better Nutrition

While progress has been made in recent years to address undernutrition (lack of sufficient daily calories), a greater challenge remains: how can we reduce **micronutrient malnutrition** (dietary deficiency of vitamin A, zinc and iron) that impacts an estimated 2 billion people around the world?

Micronutrient malnutrition results in low disease resistance and stunted growth in children, and it reduces cognitive development and economic growth. The problem is especially severe in much of Sub-Saharan Africa and South Asia, where up to 80 percent of the population in some countries are affected by lack of vitamin A, zinc and iron.

Solutions center upon improving the dietary diversity of target populations, as well as fortifying staple foods with added nutrients. The use of **biofortification** is an additional strategy that can effectively target rural, poor populations who are least able to improve their dietary diversity. By targeting the foods they eat each day (staple food crops), nutrition is delivered easily and with less cost, with minimal consumer behavioral change.

Biofortification improves nutritional content of staple food crops through either conventional plant breeding or through transgenic approaches which enables farmers to grow fortified foods for themselves. **More than 15 million people in 30 developing countries are already growing and eating biofortified foods**, with new innovations in the pipeline.

Through collaborative research, **HarvestPlus** (part of the Consultative Group for International Agricultural Research, or CGIAR) has developed iron-rich beans in Rwanda and vitamin A biofortified sweet potatoes in Uganda that deliver better nutrition to the rural communities that grow and consume them. Other crops with improved nutritional content through biofortification include rice, wheat, maize, cassava, pearl millet and sorghum. Peer-reviewed published data demonstrate that these foods are working to reduce disease incidence and improve nutritional status.

Sorghum is a resilient crop that grows well in challenging soils and climates, and is the fifth most important grain for food use globally. It is particularly suitable for biofortification to make it more nutritious for human consumption. **Africa Harvest** and **DuPont Pioneer** are presently working together to improve sorghum through the **Africa Biofortified Sorghum (ABS)** project, which improves levels and availability of vitamin A, zinc and iron in the crop. More recently, scientists at DuPont Pioneer have reported on the ability to extend the stability of vitamin A in stored sorghum by increasing

Biofortified sorghum can improve human nutrition. The biofortification of crops serves as a complementary tool alongside dietary diversity and fortification as part of a comprehensive strategy to improve global nutrition.

Credit: Kitavi Mutua

vitamin E in the seed, which protects the vitamin A from oxidation. The result is even longer period of elevated vitamin A in the sorghum grain for those who rely on sorghum as a staple food.[8]

This multi-stakeholder initiative received funding from the **Bill and Melinda Gates Foundation**, the **Howard G. Buffett Foundation** and DuPont Pioneer. Other contributions are coming from a number of Africa-based institutions collaborating to improve the nutritional profile of sorghum while also building research and regulatory capacity and strengthening seed systems.

Governments, scientists, farmers and consumers need to employ a full range of strategies to improve nutrition. Dietary diversity, fortification of staple foods, conventional and transgenic biofortification of staple crops, reducing post-harvest loss and consumer education will all be key to improving nutrition for the poorest and the most hard to reach rural populations.

Biotech Maize Reduces Labor for South African Women Farmers

Women are the quiet drivers of change towards more sustainable production systems and a more varied and healthier diet. Women comprise an average of 43 percent of the agricultural labor force of low-income countries, and up to almost 50 percent in Eastern and Southeastern Asia and Sub-Saharan Africa. **If women farmers could access the same productive resources as men, they could increase yields on their farms by 20–30 percent, lifting 100–150 million people out of hunger**.[9]

Labor demands on women during peak agricultural cycles of land preparation, planting and weeding actually hinder the ability of farmers to increase crop yields and to diversify their farm operations. Given the important role women small-scale farmers play in agriculture across the African continent, and as biotechnologies begin to be adopted by farmers of all scales, a central question arises: does GM crop technology provide gender differentiated benefits?

South Africa is the only country where small-scale farmers have been growing genetically modified maize, their primary subsistence crop, for more than a decade. In 1988, Bt maize seeds (maize hybrids with a *Bacillus thuringiensis* gene inserted making them resistant to stem borer pests) were approved. Herbicide tolerant (HT) maize seeds that enabled farmers to fight weeds and improve soil health came on the market in 2003. Then in 2009, a maize variety containing both the HT and the Bt traits ("stacked" maize) was approved and began to be adopted by farmers. By 2012, 85 percent of all maize grown in South Africa was GM: Bt single trait maize covered 29 percent of maize area; HT single trait maize covered 13 percent; and stacked maize with both Bt and HT traits covered 43 percent of all maize area.

The International Food Policy Research Institute (IFPRI) and the **University of Pretoria** in South Africa conducted research in small-scale farmer communities over eight cropping seasons as well as qualitative research with men and women in separate small groups to examine the relative gender impact of GM maize adoption in Kwa Zulu Natal (KZN) Province. These farmers were selected because they had previously participated in demonstration workshops organized by **Monsanto** in 2001 and had adopted Monsanto maize with Bt, HT and stacked traits.

With many men in rural areas leaving for urban work and physical labor made more difficult due to the disease burden of HIV/AIDS, there is a substantial need for technologies that support African women in their agricultural roles.

Credit: CIMMYT

In comparison with conventional maize producing households, the research found that both men and women preferred the stacked and HT trait maize varieties because these enabled them to save time and labor while providing higher yields. Adult female household members reduced weeding time by 10 to 12 days, a significant time savings that enabled them to spend more time growing nutritious foods or taking care of their families.[10] This represents a substantial reduction in physical drudgery, as women normally perform this particular task in the maize production cycle. Women reported being able to spend more time working in their own or community vegetable gardens or on other household work.

PROMOTING ONE HEALTH: HEALTHY PEOPLE, ANIMALS AND PLANET

One Health is a widely adopted paradigm for public health and agriculture that acknowledges the symbiotic and complex interactions between the health and productivity of humans, animals and the environment. The approach uses integrated risk management with a focus on prevention, intervention and rehabilitation in order to promote better health and disease reduction.

One Health also promotes healthy ***microbiomes*** — communities of microorganisms that live in or on soils, plants, water, the atmosphere, people and animals. Microbiomes are essential for promoting soil health, maintaining water quality, limiting the spread of infectious and non-communicable diseases, improving human and animal nutrition, preserving the efficacy of tools used in human and animal medicine, and conserving natural resources. The One Health paradigm relies on healthy microbiome communities to improve the efficiency and resilience of agricultural production, helping farmers remain competitive, especially in the light

National Microbiome Initiative

In 2016, the White House Office of Science and Technology Policy (OSTP) partnered with private industry to create the **National Microbiome Initiative (NMI)** to promote interdisciplinary research and development of microbiomes in a variety of ecosystems, including agriculture. Federal agencies have committed $121 million for cross-system microbiome research for FY2016 and 2017, and an additional $400 million will be leveraged from foundations, private industry, academic institutions and professional scientific societies.

Novozymes is the world leader in biological solutions. As the world's largest provider of enzymes and microbes, its solutions enable higher agricultural yields, help plants improve heat tolerance and draw natural phosphate more efficiently from the soil. Novozymes is helping to shape the NMI by outlining top technology and resource needs to advance microbiome research, as well as key science questions the country needs to answer.

of climate change and the rising demand for animal-sourced foods.

Microbial solutions applied to seeds improve root growth and crop uptake of essential nutrients and water, reducing the burden on the natural resource base. Solutions that improve animal health make livestock more productive and reduce their contributions to greenhouse gas emissions, while helping reduce the need for costly medical interventions to address disease and other maladies. Conservation and precision agriculture practices help soils retain water, reduce costs and improve soil health, keeping farmers productive and competitive even in dry seasons. Appropriate nutrient application stimulates the growth of nutrient-rich fruits and vegetables while preserving water quality.

The approach offers an opportunity to bring together inter-disciplinary research, knowledge and experience, providing holistic solutions for healthier people, healthier animals and a healthier planet.

One Health for Livestock and People: Innovation in Action

When livestock are healthy, it is possible to improve their milk, egg and meat productivity and reduce the overall numbers of animals needed to meet demand for animal products, thereby delivering profound benefits for the environment.

Yet one-fifth of livestock around the world are lost to disease.[11] This is associated with wide-spread animal suffering, reduced farmer profitability and is perhaps the greatest untold story of food waste today. Science-based innovation that reduces the reliance on shared-class antibiotics (those used for both human and livestock) can improve animal health while also avoiding the rise of antibiotic resistance in humans.

Mastitis, an infection of the dairy cow udder, is one example. Almost all cows experience a weakened immune system, known as immune suppression, right before and after they give birth. This puts them at risk of infections like mastitis, which is the most common disease in dairy cows in the United States. Despite continued improvements in animal care, nutrition, housing and comfort, one in four cattle in the U.S. gets mastitis, which makes them restless

and causes significant discomfort. Mastitis is the leading cause for therapeutic antibiotic treatment in U.S. dairy animals, and to treat it requires the greatest use of shared-class antibiotics in the dairy industry.

Health regulations prohibit milk with antibiotic residue from being sold. This means that each year **1.2 billion servings of milk are lost from the dairy value chain, as farmers literally pour this milk down the drain during the time period that the cows receive antibiotic treatment**. In addition, the cow's level of milk production through her entire life cycle will likely fall below her potential as she is more susceptible to contracting mastitis on a recurring basis.

The need for alternatives to protect the health of animals and preserve the long-term effectiveness of shared-class antibiotics has never been greater.

Innovation in science and research by a leading animal health company, **Elanco**, has led to the development of *Imrestor™*, a first-of-its kind immune restorative. *Imrestor™* is not an antibiotic, vaccine or hormone, but rather is similar to a naturally occurring protein that helps restore the cow's immune system so she can continue to function normally, thereby reducing the chances she will get mastitis.

Clinical tests of *Imrestor™* have proven **a reduction in the incidence of mastitis in calving cows by 28 percent in the U.S. and 26 percent in the EU** in the 30 days post calving — thereby decreasing the need for antibiotics and other treatments, along with reducing the amount of milk discarded during the treatment cycle.

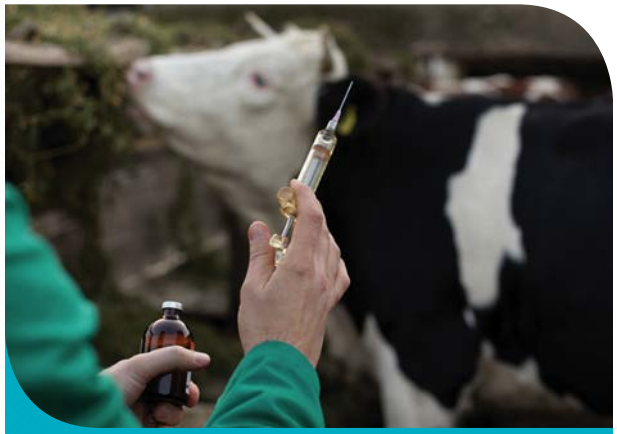
As a result, 43 countries have moved to approve the use of *Imrestor™*, including Canada, the U.S. and the EU. Embracing science-based innovation will lead to significant gains in improving animal and human health and reducing food loss and waste along the livestock value chain.

Building Capacity to Promote One Health in Food Systems in the LAC Region

Microorganisms (such as parasites, bacteria, fungi and viruses) have become increasingly resistant to antimicrobial drugs, raising the level of health risks for humans. Agriculture must play a central role to address these issues, and to reduce the disruptive impact that these new strains of microbes would have on food production and the lives of producers across **Latin America and the Caribbean (LAC)**.

Recognizing this threat and the need for urgent action, the **Inter-American Institute for Cooperation in Agriculture (IICA)**, in collaboration with the **Ohio State University Department of Veterinary Preventive Medicine** and supported with funds from the **European Union's 10th Economic Development Fund (EDF)**, is working to build technical capacity of veterinarians, diagnosticians, epidemiologists and other public health professionals in the LAC Region.

This capacity building program provides foundational and applied knowledge on the use of antibiotics and related antimicrobial agents in various animal production systems. It helps the livestock industry understand the emergence and epidemiology of antimicrobial resistance in agriculture and its impact on the health of humans, animals and the environment, as well as on international trade and commerce. The program also provides guidance to establish or enhance surveillance and monitoring systems for antimicrobial resistance in zoonotic and foodborne pathogens. It discusses the development and implementation of prevention and control interventions (including surveillance programs) specific to each country, with an emphasis on minimizing the potential impacts of antimicrobial resistance on public and animal health as well as trade and commerce.



IICA is establishing pilot programs in many Caribbean countries to provide surveillance and monitoring for antimicrobial resistance.

Credit: IICA

As of 2016, this program has trained more than 28 government officials from 14 countries, over 300 producers and more than 100 private technicians in how to identify and address these issues. The program has produced several guides covering best practices and use of veterinary drugs in bovine and aquaculture production as well as a report assessing the state of surveillance systems of veterinary drugs in livestock production throughout the region.

Bio-Innovation Promotes One Health for the Planet

More than 40 countries are on the cusp of building completely new **bio-innovation economies** that supply food, create jobs, reduce waste and improve health. **Bio-innovation is the invention, development, production and use of biological products and processes, often harnessing the power of microorganisms and enzymes that naturally improve processes across many business sectors, including agriculture, feed, fiber and fuel.** Bio-innovation contributes to new economies that improve health outcomes, boost the productivity of agriculture and industrial processes, and enhance environmental sustainability.

Bio-innovation also involves creating products that are derived from plants and renewable agricultural, marine and forestry materials to provide an alternative to conventional petroleum derived products. These products include lubricants, cleaning products, inks, fertilizers and bioplastics, as well as biodiesel and biofuels made from switchgrass, soybeans, sweet sorghum, cane, corn, jatropha, animal fats, algae and trash.

Building a bio-innovation economy creates jobs that are sourced and anchored in rural and urban areas, bringing development and well-paying technology sector positions. **Estimated direct revenue will reach $250 billion annually in the United States alone, with a total economic impact in the U.S. of $660 billion including indirect and direct economic outputs by 2030**.[12]

Realizing the benefits of bio-innovation will require coordinated policy action by governments, investments in research and development, smart regulations that encourage advanced scientific development and government's help communicating the value of such innovation to the wider society and consumer base.

FRIENDLY MICROBES BRING BIO-INNOVATION TO SUSTAINABLE AGRICULTURE

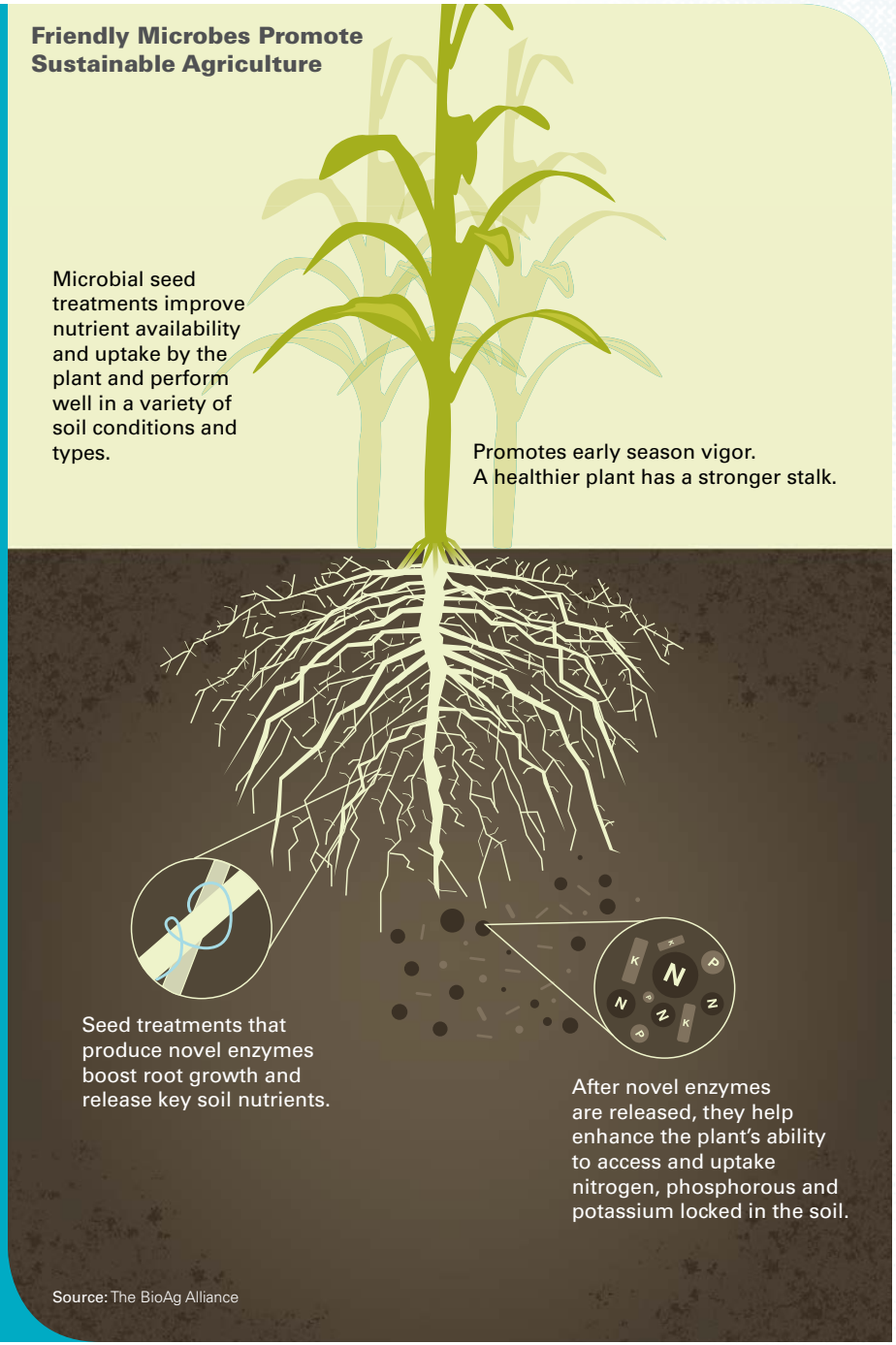
Microbes are critically important to the modern farmer, who faces the challenge of increasing the world's supply of food on a decreasing amount of arable land. **Agricultural biologicals** consist of **microbes** (tiny organisms like bacteria and fungi) that live in the environment and interact with plants, soil, animals and people in mutually beneficial ways. Long before humans started to understand agriculture, plants were interacting with tiny flocks of microbes in the soil and above ground. These friendly microbes supply plants with nutrients like nitrogen and phosphorous. They also enhance root growth for support and better access to water in the soil. Microbes improve soil quality and help plants become more resistant to stressful conditions such as heat, cold and dry weather, and even protect plants from disease and pests.

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 for farmers to use as part of a suite of sustainable practices. Through extensive scientific testing, selected microbes are harnessed to improve plant health by enhancing growth, especially in the vital early days after planting. These products serve as inoculants, helping plants absorb nutrients and protect against pests, disease and weeds.

The BioAg Alliance is developing a variety of agricultural biologicals to support a wide range of crops such as alfalfa, canola, corn, chickpea, cotton, dry bean, lentil, mustard, pea, soybean and wheat. High-value crops such as salad greens, strawberries and nuts also benefit from their use.

One such product, QuickRoots®, is used by farmers on crops as diverse as canola, corn, pulses, sorghum, soybean, sugar beets and sunflowers. Farmers apply the microbial seed product in either a wettable powder solution or in a dry format. The seed treatment produces novel enzymes that help to release key plant nutrients, potassium, phosphorus and nitrogen from soils and assist with optimum uptake to help young plants grow roots and shoots for early season vigor.

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 are contributing to sustainability by ensuring optimum use of fertilizers and water. The BioAg Alliance is at the early stages of discovering many new applications of beneficial microbes for use in the coming years.



TECHNOLOGY AND DATA HELP THE PLANET, WHILE FARMERS MAKE A PROFIT

Farmers must manage through the current agricultural business cycle by staying competitive and by participating in new markets. They must also **reduce their costs**. To do this, farmers and ranchers are adopting **precision agriculture systems** to make their crop, livestock, aquaculture, dairy and orchard operations more profitable.

Precision agriculture is the use of data and technology to increase the productivity and profitability of agricultural systems by applying inputs (fertilizers, pesticides, irrigation water, labor and machine hours) in precise amounts and with maximum effectiveness, as well as using data to improve livestock and aquaculture productivity.

Agriculture is increasingly becoming a high-tech business, not only for farmers in high-income countries, but across the globe. Accelerating the access to new technologies, data and precision systems will help farmers in low-income countries close their productivity gaps and manage their natural resource base to conserve soil and water. The potential exists in coming years for these precision technologies to help producers adapt to climate change as well as to monitor their own environmental compliance and demonstrate sustainability and productivity claims to buyers and consumers.

THE ERA OF PRECISION CONSERVATION

Precision systems enable each farmer to manage and track, year after year, progress towards maximizing the productivity of each field, while placing less productive areas into conservation or creating refuges for pollinators and biodiversity. Using their own data, precision systems also help farmers raise healthier animals and manage grazing lands for sustainability.

Through the use of equipment such as **in-field monitors** and **sensors**, farmers and service providers can record data on temperature, rainfall, soil conditions and plant growth, capturing the information for analysis and to generate models that help them make good decisions about operations and investments. **Livestock monitors** check animals for breeding cycles and disease, notifying farmers of potential problems before they spread to the entire herd. Monitors also track food and water consumed. **Machinery equipped with precision systems** of parallel steering, GPS and data history enables farmers to cover every inch of the field and avoid even the slightest overlap, saving time, costs of seeds, inputs and fuel, and reducing wear on the equipment. **Remote sensing** is widely used with **satellite imagery** to collect data. Unmanned aerial vehicles (commonly called **drones**) are used to fly over fields and generate maps and assess crop health. Precision systems can monitor irrigation, farm vehicles, livestock, greenhouses and stables, aquaculture, forests and storage of crop and livestock products and can reduce the amounts of water and fuel that are used.

Accelerating and Extending AgTech

Investment in precision agriculture technology (AgTech) is booming, with venture capital accelerator funds investing $4.6 billion in 2015 alone into new startups.[13] AgTech startups are changing the face of agriculture by rapidly developing new technologies that respond to growing demand for novel food products, more sustainable production, and convenient tools such as farm applications (apps) accessible on smartphones.

Farmers have also joined together with **Google Ventures** to create the **Farmers Business Network (FBN)**, a company that is using crowdsourced, aggregated and anonymized data to benchmark and analyze member operations. With thousands of farmer members, each can learn from one another about seeds, irrigation, tillage and rotation practices. They can determine whether their own operations are underperforming compared to others and make informed decisions about how to improve their productivity and profitability.

AgTech has the potential to be scale-neutral and customized for use in many countries. **A core requirement for extending precision agriculture more widely is increasing the availability and reliability of broadband access for farmers and producers**, enabling them to connect within their own operations as well as to global markets in real time.

In Colombia, the Center for International Tropical Agriculture (CIAT) is using drones to monitor rice and cassava crops and to detect patterns of drought or nitrogen use efficiency. Drones also help crop scientists evaluate trait performance, saving time in research so varieties can be developed that can thrive under stressful environments.

Credit: Neil Palmer (CIAT)

Caring for Soils Through Customized Technology

In Kenya, less than 20 percent of land is suitable for cultivation due to degraded and poor soils. Yet there is great potential for small-scale farmers in Kenya to understand, manage and improve their soils to reach cultivation potential and maximize their farm productivity and sustainability.

To help Kenyan farmers, **Rabobank Foundation** launched a partnership in June 2016 with the **SoilCares Foundation** to extend state-of-the-art technology tools, information and training to Kenyan agricultural service providers. SoilCares, a spin-off of one of the oldest agricultural laboratories in the Netherlands, brings its rich agricultural laboratory resources literally to the hands of farmers worldwide.

The **SoilCares Scanner** is the first device in the world providing affordable, real-time soil analyses and fertilizer recommendations. Using near infrared spectroscopy, the scanner measures soil parameters and sends lime and fertilizer recommendations, customized for the farmer, to a smartphone via the **SoilCares App**. Agricultural service providers help farmers use the information to determine which fertilizers are needed and in what quantity. With funding from the Rabobank Foundation, the scanner will be piloted in Kenya and then advanced to neighboring countries in the coming years.

Agricultural service providers use the SoilCares Scanner to provide Kenyan farmers with soil analyses.

Credit: SoilCares Foundation

Precision technology can be added to existing mechanization platforms so farmers, like Mr. Inder Mohan Sood, can move up the technology ladder over time.

Credit: John Deere

From India to Africa: SMART Solutions for Small-Scale Farmers

In high-income countries, precision agriculture (also known as "site-specific farming") began by combining **global positioning systems (GPS)** with **geographic information systems (GIS)**. These applications are used for farm planning, field mapping, soil sampling, machine guidance, crop scouting, variable rate applications and yield mapping. Many of the new innovations rely on **farm machinery platforms**: the integration on a tractor of on-board computers, data collection sensors, and GPS time and position reference systems from the tractor.

Small-scale and emerging farmers cultivating only a few hectares lack access to new technologies and services, particularly in the area of mechanization and equipment. But models and technologies geared towards the needs of smallholders are emerging, and **John Deere** is bringing experience from operations in India to Sub-Saharan Africa to help.

The **SMART** approach in Africa is a comprehensive strategy for helping these farmers with many of their needs. Building on successes in India, John Deere brings the right-sized agricultural machinery (small tractors between 36–75 horsepower), farm equipment and precision technology farm equipment to emerging farmers in Africa through agrodealers and agricultural implement resource centers. Farmers gain access to finance through partnerships with local banks that offer special solutions to meet their needs. Reliable service from dealers keeps the equipment in operation and ongoing training is provided in business skills, agronomy and machinery operation.

To take advantage of precision agriculture technology, African farmers will require high quality, high-speed broadband and mobile cellular coverage across their farms.

Broadband Innovation for Rural Areas

Broadband access is unaffordable or non-existent for nearly half the world's population, and many of those who cannot access broadband reside in rural parts of Sub-Saharan Africa. For farmers to take advantage of information and communications technology (ICT) in agriculture or to eventually gain access to more precision agriculture opportunities, broadband must become more available and affordable.

While telecommunications network operators in Africa are deploying fiber-based, high-speed broadband infrastructure, the cost of getting it to rural areas is prohibitive; in addition, many rural areas lack utility power. One way to solve the problem is to use wireless radio links, which can be used for "last mile" access or even longer distance connections. Many new wireless devices can leverage the so-called TV white spaces spectrum (TVWS, operating on UHF frequencies).

In Kenya, an innovative solution known as the **Mawingu Project** is now being tested. It seeks to connect unserved rural communities with affordable, high-speed, solar-powered broadband. The **Communications Authority of Kenya (CAK)** issued **Microsoft East Africa** a trial authorization to use TVWS technologies to deploy affordable high-speed broadband, delivered to solar-powered internet kiosks, or "solar cybers," throughout rural communities in Kenya. The Mawingu Project provides no charge access to broadband internet; libraries, schools, farms and local government offices are able to access the internet and charge wireless devices for free. The project is now serving as a basis for other communications providers in Africa and around the world to permit access to TVWS so that rural areas can be reached with high speed broadband.

The Mawingu ("cloud" in Swahili) Project extends broadband to rural Kenya.

Credit: Microsoft

POLICY 3

Enhance Private Sector Involvement in Agriculture and Infrastructure Development

To maximize the productive potential of investments in agricultural R&D and to facilitate regional and global trade, governments and their partners need to invest in transportation, electricity, financial and communication infrastructures.

Road and railroad improvements enable more farmers to get their products to market as well as reduce post-harvest losses along the way. Reliable telecommunications systems provide farmers with timely market information, while access to banking and finance enables them to manage and expand their operations.

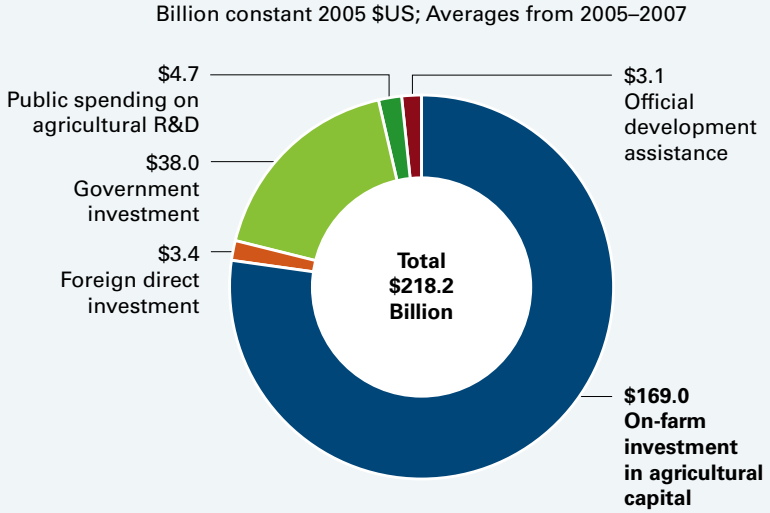
$1 TRILLION (USD)

The gap between current and needed investments for infrastructure in low- and middle-income countries.[1]

The private sector has a vitally important role to play in ensuring that critical infrastructures for agriculture are developed and improved. Accordingly, policymakers should look for opportunities to leverage public sector investments with private sector capital and expertise in ways that share risk and generate greater returns than either sector could achieve independently.

Farmers and producers are already the largest investors in the agricultural value chain. Policies that secure and promote farmer access to land, water and improved inputs enable farmers of all scales to remain competitive even during the challenging phases of business cycles and help them respond to changing climate patterns. An enabling policy environment also supports their productive potential by generating new market opportunities, increasing their access to affordable financing and improving the environmental sustainability of their operations.

Figure 3.1: Sources of Agricultural Investment in Select Low- and Middle-Income Countries



Source: Sarah K. Lowder, Brian Carisma and Jakob Skoet, "Who Invests in Agriculture and How Much?" FAO, EAS Working Paper No. 12-09 (December 2012).

A review of agricultural investment sources in low- and middle-income countries by the UN Food and Agriculture Organization found that 78 percent of agriculture investments come from on-farm investment in agricultural capital by farmers themselves. The remaining 22 percent comes from government expenditures, public sector agriculture R&D, foreign direct investment and official development assistance.

This chapter provides examples from the U.S., Africa, Asia, Latin America and the Middle East highlighting how an enabling policy environment for private sector involvement in agriculture and infrastructure creates an "ecosystem" in which agribusiness, farmers and producers of all scales can grow and thrive.

LAND, WATER AND CAPITAL: SECURING THE INDISPENSABLE ASSETS

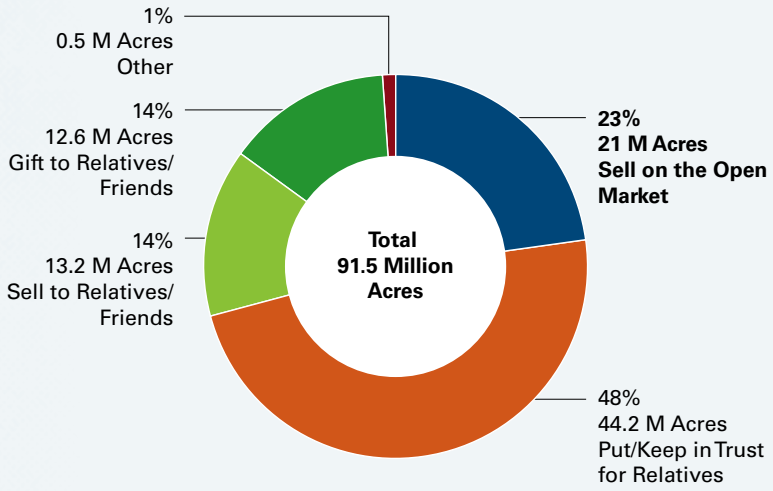
For farmers around the world, land and water are indispensable assets, but many face obstacles to securing and maintaining access to them. Millions of small-scale farmers around the world are undercapitalized because they do not have legal title to their most important capital asset, their land. Many of them, and millions of others, cannot get access to enough water for livestock and crop irrigation to stabilize and grow their operations.

Enabling small-scale farmers to secure access to land, particularly those who are young or new to farming as well as established farmers who wish to expand or invest in the productivity and sustainability of their operations, will require affordable credit packages and other financial incentives.

Meanwhile, water scarcity and climate change are forcing farmers to harvest water as deliberately as they harvest their crops. Data-driven water management policies can help farmers remain productive even in dry seasons and in drylands. Governments can encourage agribusiness to partner with communities to improve their water quality and management practices. Risk management tools, such as **Weather Index Insurance**, can protect farms from failure, even in the face of climate change.

The following case studies describe specific challenges faced by farmers in the U.S., Benin, India and the Middle East and strategies being employed to ensure that they have access to the productive inputs they need to be competitive and sustainable.

Figure 3.2: Projected Ownership Transfer of U.S. Farmland & Ranchland, 2014–2019



Source: USDA NAAS, 2014 Tenure, Ownership, and Transition of Agricultural Land Survey

Between 2014 and 2019, 91.5 million acres of U.S. farmland and rangeland will be transferred to new ownership. Only 21 million of those acres, representing just 2.5 percent of the total agricultural land in the U.S., will be available for sale on the open market to be purchased by farmers who wish to expand their operations or by new entrants into the farming sector. The remaining 70.5 million acres will be kept within families.

Affordable Financing and Land Access Options for U.S. Farmers

U.S. farmland and ranchland is some of the most productive and expensive agricultural land in the world. Its value is further enhanced by the fact that it is usually kept in trust, gifted or sold within families and is rarely available for sale on open market (Figure 3.2). Without a significant capital investment, it is difficult for farmers to expand or for new and young farmers to establish themselves.

One solution is for farmers to rent the land they work from institutional investors, which offers an affordable way for them to grow their operations without incurring the debt and risk associated with purchasing land. Institutional land investors build long-term leasing relationships with farmers and invest in capital improvements that increase farm productivity.

Laws restricting institutional investors in land can hurt farming communities by

DEPRIVING farmers access to affordable sources of investment

In 2014, a farmer named **Charlie Baucom** wanted to expand his business, **Bentwood Farms**, beyond the 5,000 acres of corn, soybeans, wheat and canola he farmed in North Carolina. Buying additional acreage did not make financial sense, so Bentwood Farms began renting land from **Farmland Partners Inc.**, a publicly-traded farmland real estate investment trust that makes long-term investments and improvements in agricultural land. Since establishing a relationship, Baucom has

Institutional investors provide farmers like Charlie Baucom with the capital they need to expand their operations and improve their land.

Credit: Charlie Baucom, Brentwood Farms

come to Farmland Partners whenever he identifies an opportunity to farm land he is not interested in purchasing himself. In two years, he has increased the acreage he cultivates by more than 80 percent, while minimizing the risk for his business and stabilizing and diversifying his cash-flow position.

Farmland Partners has also made capital intensive improvements to Charlie's farms that he otherwise would not be able to make. In 2015, Baucom worked with Farmland Partners to improve a 2,106-acre property in South Carolina. The farm has excellent soils and the region has a long growing season, but the farm was not able to reach its maximum corn yield due to flooding in mid-spring and excessive heat in the summer.

To improve the farm's water management system, Farmland Partners cleared timber, reshaped the fields and added surface drains and a subsurface tile system. He created a central drain so that water from the field could be recycled and re-applied through new irrigation pivots. As a result, plants always have the appropriate amount of water, either in the root system or on the surface. Baucom also consolidated 85 separate tracts into five large fields, so the entire farm can be managed more efficiently and planting times have been reduced from seven days to two.

With Farmland Partners' investment, Baucom's yield has increased from about 120 bushels of corn per acre to approximately 200 bushels per acre of dryland corn. The investment has also allowed for an additional soybean crop each year, increasing yields to 25 to 30 bushels per acre, without spending additional resources on soil fertility. Bentwood Farms now makes a higher rent payment on the additional capital Farmland Partners has invested, and itself has become a more profitable and sustainable producer.

Securing Land Tenure

Millions of small-scale farmers struggle to access affordable credit because they lack legally recognized property rights. In low-income countries, the right to occupy, cultivate, inherit, lease, buy or sell land is often determined by a complex system of social customs that are granted and arbitrated by communal authorities (sometimes called "customary" or "tribal" authorities). Communal rights may be recognized by civil authorities as well, but they do not have the same legal standing as land titles or leaseholds granted by the state.[2] Formal lenders see communal tenure rights as a risky investment and are reluctant to extend credit, regardless of the productive potential of the land.

Well-managed communal tenure systems have some benefits.[3] Communal tenure systems are contingent upon community membership rather than the ability to pay. This makes them more flexible and responsive to community needs and enables a larger number of people to become landholders. Nonetheless, many communal tenure systems are dominated by social and patriarchal hierarchies that disenfranchise vulnerable groups. As a result, gender, age and community standing often determine the quality, quantity and terms of the landholdings. Furthermore, without civil legal protections, communal landholders have little recourse if their land is appropriated by customary or state authorities.

Securing land tenure improves the monetary value of land **productivity by 40%** and the welfare of landowners by 15%[4]

In these circumstances, communal landholders, particularly women, are less likely to make investments in improved seeds or fertilizer, suppressing their earning potential and making it difficult to save for capital purchases, such as mechanization and irrigation technologies. Likewise, long-standing and widespread land disputes stifle the sale, purchase, leasing and inheritance of land, effectively freezing the land market, discouraging productive investment and stifling economic growth.[5]

Credit: Kelly Winquist, John Deere

Registering Land Title in Benin

In **Benin**, agricultural productivity growth has been suppressed by the absence in some areas of written ownership records and a customary land tenure system that can make land transactions difficult.[6] Many families lack legal evidence of tenure and the boundaries of the landholding itself are often disputed, even within the family. Female-headed households can be especially vulnerable to eviction.

As part of the **Millennium Challenge Corporation (MCC)** compact between the U.S. and Benin governments, the MCC invested $31 million (USD) in the **Access to Land Project** to support land policy reforms, strengthen the land tenure security of landholders and support rural land governance. In 2007, Benin passed a **Rural Landholding Law**, which recognized customary tenure rights as equal to civil property rights. The Compact worked to extend Benin's pilot efforts at establishing community-level rural landholding plans, or **Plan Foncier Rural (PFR)**. PFRs are implemented at the village level and attempt to demarcate the boundaries of parcels, including agricultural fields. Residents in PFR villages were able to receive, for a fee, individual land use certificates, which constitute legal evidence of recorded land rights.

An independent randomized control trial (RCT) evaluation, measuring early results (approximately one year after PFRs were issued) found that land demarcation through the PFR led to an increase in long-term investments, such as tree planting and perennial crops.[7] In addition, women in PFR villages were more likely to leave land fallow — an important soil conservation practice. The final evaluation of the Access to Land Project is expected in 2017 and will assess whether there was a continued increase in long-term investment, as well as increases in agriculture output, farm yields and the use of productivity-enhancing inputs such as labor, fertilizer and improved seeds.

Harvesting Water for Dry Seasons and in Drylands

Around the world, farmers with rainfed crops and livestock herds are struggling to adjust to climate change and shifting weather patterns. Farmers observe that the rain seems to come too early or too late; when it does come, there is either too little or too much. For millions of farmers, extreme and interminable drought means no crop and no food.

80%
of global agriculture is rainfed and is responsible for much of the food consumed by poor people.

For these farmers, harvesting water is as important as harvesting their crop. They need tools and techniques to more efficiently capture, store and manage water in order to remain productive during dry seasons and to mitigate the impacts of climate change. In rural **India**, consistent access to water is a critical issue. Two thirds of agriculture in India is rainfed, but the seasonal monsoons alternate with long, dry periods, making it difficult for communities to maintain an adequate groundwater supply.[8]

The **Mosaic Villages Project**, a partnership between **The Mosaic Company** and the **Sehgal Foundation**, funded the construction of four new check dams in Santhawadi, Pathkhori, Nangal Hasanpur and Khohar. A check dam is a barrier across a drainage ditch or small waterway that counteracts erosion by reducing water flow velocity. The check dams capture and store rainwater, which is then funneled into the underground aquifer, recharging groundwater levels and reducing salinity so that water can be used for consumption or irrigation. Together, the check dams have directly and indirectly benefitted more than 30,000 people, and have a total reservoir capacity of more than 14 million gallons.

The Mosaic Villages Project funded the construction of several "check dams" in India, allowing monsoon rainwater to be captured and stored, recharging groundwater levels.

Credit: The Mosaic Company

The Middle East and North Africa have the lowest levels of renewable water resources per capita and the highest proportion of water withdrawals of any of the world's major regions.

Credit: ICARDA

Producers and policymakers in the chronically water-stressed **Middle East and North Africa (MENA)** region urgently need data on field-level evapotranspiration, as well as the tools to use that information to predict crop yields.

With funding from **USAID**, the **Robert B. Daugherty Water for Food Global Institute at the University of Nebraska** and the **National Drought Mitigation Center at the University of Nebraska-Lincoln** are working with farmers and government planners in the MENA region to improve drought monitoring and increase data-driven decision-making for water usage. The research team is developing composite drought indices that incorporate data collected from satellite remote sensors with data collected on the ground. Data analysis is provided to planners who use it to calculate the water balance within watersheds and estimate water productivity at field scales.

The team is also working with government agencies and producers to better understand the water needs of the MENA region as well as its drought vulnerabilities. Insights gained from those meetings will help improve the effectiveness of data tools developed during the project.

Maximizing Productivity and Reducing Risk

During periods of prolonged drought, small-scale farmers are faced with difficult choices. Those with more assets raise cash by selling cattle and equipment or by leasing their land, while the poorest farmers, with fewer assets, cope primarily by reducing their consumption, particularly of food. Both coping strategies have generational impacts on the health and economic prospects of the family and the productive capacity of their land.

Drought Tolerant (DT) seeds and **Weather Index Insurance (WII)** can help mitigate the financial and food security impacts of drought. **USAID's Feed the Future Initiative** and the **University of California at Davis** are developing a drought mitigation approach that combines DT seeds and WII to stabilize farmer incomes while reducing the cost and risk for insurance providers.

In Ecuador, researchers found that DT maize seeds offered modest-to-strong protection against yield declines during 80 percent of the drought events. However, the other 20 percent of the time, droughts were so severe that the yield protection advantages of DT seeds declined and farmers were forced to draw down assets or decrease consumption to supplement their incomes.[10] Based on this experience, researchers proposed that farmers rely on DT seeds as their first line of defense, but if the drought strengthened or lengthened and yields fell below a predetermined level, then the weather index insurance would kick in to stabilize farmers' incomes and allow them to retain their assets.[11]

Currently, weather index insurance is not widely available and for farmers operating with very low margins, insurance is not a priority expenditure. Drought tolerant seeds for maize are more widely available, but many small-scale farmers have yet to adopt DT and other improved seeds. Nonetheless, policymakers and development agencies continue to develop strategies that combine technology and financing mechanisms for stabilizing farmer incomes and food security during drought, while ensuring they have sufficient resources and assets to improve their productivity when the drought subsides.

Improved seeds enable farmers to maximize the productivity of their land while minimizing their need for other inputs, such as water and labor. Nonetheless, uptake of this technology has not met expectations, even in Africa where it could provide a significant advantage for farmers. Agrodealers can play an influential role in educating farmers about the benefits of improved seeds and the best practices for planting and cultivating. At the same time, seed companies are working to improve the seed value chain so that small-scale farmers can access the quantities they need at a price point they can afford.

Pictured above: Nicholas, a farmer and agrodealer in Zambia, uses test plots to demonstrate how various improved seeds and application methods are working in his soils so his neighbors can decide what will work best for them.

Credit: Ann Steensland, GHI

PRODUCTIVE INFRASTRUCTURE INVESTMENTS

The 2007–2008 food price crisis brought the issue of post-harvest losses (PHL) to the forefront of public debate, along with an exploration of strategies to reduce PHL throughout the value chain to reduce the environmental impact of food production as well as contribute to food security. But achieving lower levels of PHL on a wide scale requires investments in technologies that help prevent loss, as well as significant investments in overall infrastructure and behavioral change on the part of consumers and retailers.[12]

Investing in paved roads is critical to reducing PHL; investing in railroads and electricity also helps considerably.[13] By investing in infrastructure and technologies for transportation and electricity, large additional benefits to other sectors of the economy will accrue as well. At the same time, econometric research shows that investing in agricultural research and development (R&D) achieves very high benefits to cost ratios as a strategy for food security by greatly reducing the costs of food globally.[14] Clearly there needs to be investment on both fronts in order to achieve food security for consumers, profitability for producers and to reduce the environmental impact of PHL.

In 2014, multilateral and bilateral lending for infrastructure totaled $130 billion, meeting only 15 percent of the global infrastructure gap.[15]

Credit: Graham Crouch/World Bank

Strengthening the Tomato Value Chain to Improve Nutrition in Nigeria

In Nigeria, nearly 30 percent of children under the age of five are vitamin A deficient, a condition that can lead to blindness and increased risk of disease and premature death.[16] Tomatoes are an excellent source of vitamin A and Nigerian farmers produced 1.8 million metric tons of tomatoes in 2010, making their country the 16th largest producer in the world.[17] But the tomato supply chain is poorly organized and underdeveloped, and as a result **half of the annual tomato harvest never reaches the market**.[18] Meanwhile, Nigeria imported 150,000 metric tons of processed tomato products in 2014, valued at $160 million.[19]

The Geneva-based **Global Alliance for Improved Nutrition (GAIN)** has convened a coalition to develop solutions for reducing tomato losses that are market-based, nutritionally focused, locally adaptable and financially sustainable. The **Postharvest Loss Alliance for Nutrition (PLAN)**[20] brings leaders from government, finance and academia together with representatives from Nigeria's tomato industry, including aggregators, processors, packagers, and cold chain operators. The Alliance is targeting specific elements in the supply chain for improvement: **crating and cooling** technologies to protect prevent spoilage; a larger more reliable fleet of **transport vehicles**; new **processing** technologies and **financing** models to increase capacity; and **outgrower** schemes to link processors with farmers.

Growers, traders and processors also need technical assistance in negotiating contracts, tracking inventories, re-tooling and maintaining machinery, food safety protocols and networking within the industry. Businesses with the capacity to scale-up and innovate are receiving technical assistance and access to grants or affordable financing so that they can experiment with technologies and implement new approaches.[21]

Nigeria is the 16th largest producer of tomatoes in the world, but due to a poorly organized value chain and lack of infrastructure, half of the tomato harvest never reaches the market.

Credit: Global Alliance for Improved Nutrition (GAIN)

Strengthening the tomato value chain will not only give Nigerian producers access to a robust and growing market, it will also provide low-income consumers a safe, affordable source of nutritious food that will improve the health of millions of children.

INVESTING IN SUSTAINABLE VALUE CHAINS

Climate change and land degradation, along with the decline in critical natural resources are driving actors along the agricultural value chain to produce, manufacture, transport and retail food more sustainably. Sustainable value chains are also driven by market forces, particularly by consumers who are increasingly interested in buying — often at premium prices — products that are responsibly and sustainably sourced.

Improving the sustainability of an agricultural value chain requires a significant investment in research, technology development and training, as well as certification processes to inform consumers about sustainability achievements. Public-private partnerships bring together knowledge and funding to transform value chains and create new market opportunities for participants of all scales in the agricultural value chain.

To successfully monitor progress toward sustainability, metrics for food and nutrition security outcomes need to be integrated into a broader set of indicators that measure the environmental, social and economic impacts of agricultural value chains.[22] **More inclusive sustainability metrics can help policymakers make strategic investments** that not only improve food and nutrition security, but do so in a way that maximizes the use of scarce natural resources and produces economic and social value for people along the agricultural value chain.

The Economist Global Food Security Index (GFSI) sponsored by DuPont uses tested indicators to evaluate food affordability, availability and quality and safety at the country level. An analysis of GFSI trends since 2012 revealed that the most influential indicators for GFSI scores are political stability, presence of extensive food safety net programs, access to financing for farmers and investments in storage and transport infrastructures.[23]

URBAN AND INFORMAL FOOD SYSTEMS

By 2050, two-thirds of the world's population will live in cities. This has generated renewed calls for the private sector, particularly the finance industry, to invest in and support small and medium-scale enterprises (SME) in the food value chain.[24] In the near term, medium-scale producers, or consortiums of small-scale producers, who have the capacity to expand their operations are more likely to benefit from this new wave of investment.

Independent small-scale farmers will continue to rely on the informal food value chain, selling their products in local markets or to traders who supply larger buyers. Informal markets also contribute to the food security and nutrition of low-income people in urban areas.[25] In South Africa's urban centers, low-income people purchase their monthly supply of staple foods, such as mealie meal, from formal retail outlets, but perishable products and ready-to-eat foods are purchased at local food markets or from street vendors.

South Africa's informal food sector is a significant part of the agricultural economy. It is the country's second largest potato buyer, and **Fresh Producer Markets**, the largest potato buyer, purchases more than half of its supply from informal traders.[26] Given the importance of the informal food sector to producers, consumers and the economy, policymakers need to consider how to increase the sustainability and safety of food produced and sold informally, and how to improve the working conditions and social protection of those involved in this vibrant and growing part of the food value chain.

In some African cities, 60 percent of people are employed in the informal food sector.[27]

Fish Feed the World

Fish are an essential source of food, nutrition and income for hundreds of millions of people and increasing the sustainable production of fish is essential to meeting food demands of 9.7 billion people in 2050. Global annual per capita fish consumption has doubled from 9.9 kg per person in the 1960s to 20 kg per person in 2014.[28]

Aquaculture, or the production of fish in cages or purpose-built ponds, has grown rapidly from 55.7 million tons in 2009 to 73.8 million tons in 2014.[29] Still, the majority of global fish production comes from "captured" or wild-caught fish (93.4 million tons), especially in low-income and lower middle-income countries. The 14 countries of the Southern African Development Community produce 2.4 million tons of captured fish each year, accounting for 27 percent of the global "captured" fish production.[30]

Improved practices in fish husbandry are increasing the productivity of fisheries and helping fishers adapt to climate change. To meet the growing demand in a way that protects the natural resource base, additional investment in aquaculture technologies and best practices are needed, as well as a focus on transforming small-scale capture fisheries to aquaculture production. Consumer demand for sustainably sourced fish will be a critical market force driving an increase in aquaculture production.

Credit: Sylvann Borei/WorldFish

Access to Finance, Standards and Networks Builds a Sustainable Salmon Industry

Aquaculture production has steadily increased over the past two decades and is now the fastest growing animal protein sector in the world.[31] Salmon farming has been an important part of the growth, with Chile being the world's second largest producer.

As one of the country's largest industries, salmon production is important to the Chilean economy and it supports more than 70,000 jobs.[25] Yet growth in salmon production combined with inefficient aquaculture practices threatens the biodiversity of the region and has led to social tensions between the salmon producers and local inhabitants.

To address these issues, in 2011 the **WWF** (World Wide Fund for Nature, formerly the World Wildlife Fund) and the Dutch multinational financial services company **Rabobank**, a major financier of salmon aquaculture in Chile, formed **a strategic partnership to reduce negative environmental and social impacts of salmon farming in the country's biodiverse Patagonia region**. A key goal is to demonstrate that sustainable production along with biodiversity conservation can generate attractive financial results.

Through the partnership, Rabobank´s customers are adopting sustainable practices that conserve biodiversity and create long-term successful business models. At the center of the approach is the **Aquaculture Stewardship Council (ASC) standard certification and consumer labelling program** for responsibly farmed seafood, which promotes industry best practices that minimize the environmental and social footprint of commercial aquaculture. A three-year **Clean Production Agreement**, sponsored by WWF Chile and signed by six of the largest Chilean salmon companies, the Chilean government and maritime entities, secured industry funding for research into the impact of aquaculture activities on dolphins and blue whales and to implement changes in production methods aimed at reducing adverse impacts.

WWF and Rabobank will unveil new initiatives in 2016–2017 to expand and improve the ASC certification process and to raise further awareness of sustainable aquaculture practices that mitigate environmental and social impacts, while also promoting the long term financial success and sustainability of business operations for the salmon producers.

FARMED RESPONSIBLY asc CERTIFIED ASC-AQUA.ORG TM

In addition to promoting the ASC label and the importance of addressing environmental and social impacts of salmon farming, WWF and Rabobank have conducted an ecosystems services review on salmon aquaculture in Chile and created links between producers and buyers in key markets.

POLICY 4

Cultivate Partnerships for Sustainable Agricultural Growth and Improved Nutrition

In response to the food price crisis of 2007–2008, multilateral institutions, governments and industries have established public-private partnerships (PPPs) that agree to share the risks, responsibilities and benefits of their joint investments to increase the productivity and sustainability of agricultural production and improve the nutrition and livelihoods of small-scale producers.[1]

In the agricultural development context, PPPs do not follow a set model and are formed to achieve a variety of objectives, including building road and rail infrastructures connecting farmers to urban areas, developing essential agricultural technologies and disseminating them to farmers, creating reliable markets for small-scale producers through contracting models, or opening up new financing opportunities so farmers and agricultural entrepreneurs cans expand their businesses.

The U.S. has leveraged
$100 BILLION
in private sector investments to address poverty, agricultural development and food insecurity[2]

In 2016, the **International Fund for Agricultural Development (IFAD)** published a blueprint for **Public-Private-Producer Partnerships (4Ps)** as an expanded paradigm for PPPs that advocates for the inclusion of producer groups, specifically small-scale farmers, in the design, management, monitoring and evaluation of partnerships for sustainable agriculture value chains. Producer groups not only provide the commodities needed by the private sector, they bring essential resources to the table such as knowledge of local growing conditions, access to land and water, capital investment and labor. 4Ps can strengthen local buy-in, build leadership capacity and help achieve scale. They can also provide women and youth with opportunities to shape and benefit from the agricultural value chains that they rely on for income and food.

4P-style programs in **India** and **Guatemala** help small-scale farmers move out of poverty and achieve greater food security through improved crop productivity. The **Mosaic Villages Project** harnesses the resources of **The Mosaic Company** and local implementing partners to train farmers in balanced crop nutrition and agricultural management practices. In Mewat and Alwar, two of India's most impoverished districts, Mosaic has partnered with the **Sehgal Foundation** to create the **Krishi Jyoti Project**, which means "enlightened agriculture." Krishi Jyoti has now reached 45 villages and has been responsible for the cultivation of nearly 9,000 acres of farmland. The project has directly benefited more than 20,000 farmers.

In Guatemala, indigenous farmers in rural areas grow about 75 percent of the food they need to feed their families. Mosaic's implementing partner,

Since 2008, The Mosaic Villages Project has helped 20,000 farmers in India improve their productivity and livelihoods. The Mosaic Company provides cash grants and the time and talents of Mosaic agronomists who work alongside the Sehgal Foundation in training local farmers on balanced crop nutrition and agricultural best management practices.

Credit: The Mosaic Company

U.S. COMMITMENT TO SUSTAINABLE AGRICULTURAL DEVELOPMENT

In 2009, as part of a global commitment for agricultural development and food security, the United States pledged $4.2 billion toward a $22 billion global goal. As of 2014, $2.29 billion had been distributed principally through USAID, the Global Agriculture and Food Security Program (GAFSP) and the Millennium Challenge Corporation (MCC).[3] U.S. Government annual outlays for all food security and agriculture programs (including those managed by USAID, the Agriculture and Treasury Departments, MCC, the Peace Corps and the U.S. African Development Foundation) grew steadily from $1.7 billion in FY2010 to $2.6 billion in FY2013, before declining slightly to $2.4 billion in 2014.[4] These funds are supplemented by investments in global nutrition programs ($101 million in 2016).[5]

In 2010, the Obama Administration created the USAID-led **Feed the Future Initiative (FTF)** to concentrate U.S. investments in agricultural development, food security and nutrition in select "focus countries." Nineteen countries were chosen; 12 are in Africa, four in Asia and three in Latin America and the Caribbean. By 2015, Feed the Future succeeded in boosting rural family farming incomes in these countries by $800 million.[6] In Africa alone, FTF has provided nearly 2.5 million farmers access to improved agriculture technologies and practices and has generated $600 million in new rural loans.[7] In July 2016, the **Global Food Security Act (GFSA)** authorizing the FTF was passed by the U.S. Congress and signed by President Obama. The legislation ensures that the core tenants of FTF will guide U.S. development assistance for years to come.[8]

HELPS International, works to increase farmers' productivity in maize crops, improve native seed quality through seed banks and access to maize storage technology, cook stoves and water filters. A 2014 independent evaluation by Deloitte confirmed that average maize yields had grown from 0.8 to 4 metric tons per hectare. Deloitte's evaluation also found that yields are doubling in nearby villages as neighbors share what they learned in the HELPS program.

Partnerships such as the Mosaic Villages Project, supported by an enabling policy environment, help cultivate productive, resilient communities capable of weathering political and economic uncertainties.

PRODUCTIVE PARTNERSHIPS BUILT ON GENDER EQUITY

Gender inequities in agricultural production have implications for food security, nutrition and sustainability. Forty-three percent of small-scale farmers in developing countries are women, who tend to be the primary source of labor for planting, cultivating and harvesting.[9] Men are more likely to be responsible for the marketing and selling of crops, and therefore receive and control how the income is spent. As a result, women have limited or no authority in household decisions regarding the purchase of agricultural inputs, including productivity enhancing technologies such as improved seeds and fertilizer, irrigation equipment, mechanization and post-harvest storage.

30%

The amount yields would increase if women farmers had equal access to productive inputs[10]

A gender-based assessment of the purchases and utilization of **KickStart International** irrigation pumps in Kenya and Tanzania shows that men are far more likely to purchase irrigation pumps, to choose an irrigation pump model that they like (even though the women who used them preferred different models), and to determine which crops would be irrigated.[11]

Between 2008 and 2013, KickStart International sold 38,500 irrigation pumps in Kenya,[12] of which only 5,000 were sold directly to women. Approximately 8,000 pumps were sold to women and men jointly or to farmer cooperatives and aid groups, while 25,000 (52 percent) were sold to directly to men. Interviews revealed that men preferred to irrigate high-value cash crops, such as tomatoes, which they personally market and sell, retaining control over the income these crops generate.[13] Given the choice, women preferred to irrigate leafy vegetables, such as kale and amaranth, which they prepared for their families and sold to neighbors, generating income that they controlled themselves.

Without access to or control over productivity-enhancing inputs, the household's primary producer is less efficient and the farm is less productive and sustainable over time. If women continue to face these types of obstacles in accessing productive technologies and techniques, they are likelier to put more land into production to increase their output, which will increase their labor burden and has implications for the release of more carbon into the atmosphere and the damaging of fragile ecosystems.

Empowering Women in the Agricultural Value Chain

Millions of women access agricultural inputs, credit and markets through farmer cooperatives. Cooperatives concentrate the market power of women who might otherwise be marginalized by a male-dominated agricultural system. Not only do farmer cooperatives give women a greater voice, they do so in a market-based value chain approach that emphasizes the economic viability and social transformations needed to secure the advantages for women over the long term.

The coffee industry is learning that **empowering women is good for business**. In order to meet projected global demand, coffee production will need to increase three-fold by 2050.[14] To meet this demand in a way that protects the fragile ecosystems where coffee is produced, small-scale farmers must increase their productivity, otherwise a land area four times the size of Costa Rica may have to be put into production.[15] If this were to happen, the carbon release generated by deforestation would exacerbate climate change and further deplete the natural resources that coffee producers rely on.

80%
of global coffee production comes from farmers who live on less than $1 per day.[16]

One of the major constraints to increasing the productivity and sustainability of coffee production is that women contribute most of the labor for planting, harvesting, processing and sorting coffee beans, and yet the key elements of production, including land, agricultural inputs, credit, training and market information, are controlled by men.[17]

In 2016, **ACDI/VOCA**, a leader in agricultural value chain development, began a pilot project with two coffee cooperatives in Ethiopia that expressed an interest in improving their gender equity. Farmer cooperatives are not segregated by gender in Ethiopia, so increasing women's participation and leadership will give them greater influence in coffee production, and strengthen the cooperatives by improving the quality and volume of their members' crops. It will also expand women's access to marketing and processing opportunities in the coffee business. Each cooperative nominated a gender-balanced group made up of male and female spouses, female household heads, single males and cooperative leaders to participate in workshops to sensitize participants to gender issues and develop plans to improve gender equity in their organization and leadership. ACDI/VOCA is providing a gender advisor to assist the cooperatives and monitor their progress.

While the Ethiopia case is promising, in countries where women struggle for basic human rights, such as the dryland regions of North Africa and the Middle East, women's farmer cooperatives face an uphill battle. The **International Centre for Agricultural Research in Dry Areas (ICARDA**) analyzed four value chains in Morocco (argan, rose, cactus and saffron) and found that institutional weaknesses and cultural expectations were limiting the benefits of the country's **Rural Women's Cooperatives (RWCs)**.[18] The extension services and market analyses provided by RWCs were often outdated and incomplete, resulting in disengagement of the membership. Cultural norms excluding women from selling directly in the marketplace reduced their sales opportunities and suppressed their potential incomes. While women who were members of RWCs earned more than those who were not, their higher incomes were still usually less than the legal minimum wage. As a result, RWCs were seen by policymakers and some development agencies as a social welfare program, not as an economic development initiative worthy of investment and support.

ICARDA is working to improve the quality of extension and market services offered by RWCs, focusing on profit-making opportunities that take into account family expectations on women's time. This shift in mindset about RWCs toward a self-sustaining sources of income based on production, processing and marketing will improve the effectiveness of the RWCs as a source of productivity and empowerment.

Pathways to Productivity and Nutrition

Reducing malnutrition and obesity are essential for economic productivity and growth, particularly in agriculture. Malnutrition leads to stunted physical growth, cognitive impairments and increases the risk for chronic disease, all of which make farmers less productive and make it more difficult for people in rural communities to develop off-farm enterprises.[19]

In order to meet targets for reductions in stunting (low height-for-age), wasting (low weight-for-height)

Credit: Ariel Javellana

and women's anemia, and to increase exclusive breastfeeding in low- and middle-income countries, **the World Bank estimates that governments will need to increase their nutrition-related expenditures by a factor of 2.3 over 10 years and donor funding will need to increase by a factor of 3.6 in the same period, for a total investment of $70 billion.**[20]

$1
investment in nutrition generates up to
$48
in better health and productivity[21]

While both men and women have roles to play in reducing malnutrition in the household, women are more likely to spend money on "reproductive" goods, such as nutritious foods, school fees or health care. Increasing a woman's income through productivity gains and access to agricultural markets can improve the nutritional status, health and earning potential of herself and her family. Still, recent studies have shown that the linkages between agriculture, empowerment and nutrition are not that straightforward.[22]

Increasing agricultural productivity requires two things that most poor women lack: financial resources to purchase productive inputs and time to learn new skills or develop new markets for their products. Without resources to buy productive inputs such as hybrid seeds, herbicides or irrigation technologies, a woman will spend more time planting, weeding and harvesting to increase her output. She may also spend time marketing and selling her products, further reducing the number of hours she has for reproductive tasks, such as childcare, eldercare, cooking and housekeeping, which in most contexts she will still be expected to perform.

A study of agriculture-nutrition linkages in Zambia found that for the poorest households the best agricultural pathway to improving nutrition is for women to increase the production of nutrient-dense foods.[23] If women have access to assets or credit and can purchase time-saving agricultural inputs, the best pathway to improving nutrition is increasing the production of cash crops or high-value crops, such as fruits and vegetables, using the increased income to purchase nutritious foods. While circumstances vary greatly from one community to another, **research in Africa and Asia confirms that identifying women's time and resource constraints is essential to improving both agricultural productivity and maternal and child nutrition**.

Off the Farm and Out of the Kitchen

In addition to increasing the productivity of women on the farm, it is essential to create opportunities for women to earn income and build businesses along the agricultural value chain.

Madame Astou Gaye Mbacke, owner of Touba Darou Salam Cereal Processing Unit in Senegal.

Credit: Feed the Future Innovation Lab for Food Processing and Post-Harvest Handling

Madame Astou Gaye Mbacke, owner of **Touba Darou Salam Cereal Processing Unit** in **Touba City, Senegal**, uses innovative cereal grain processing technologies to produce affordable, high quality flour products. With the support of **U.S. Government funding and other donor programs, Purdue University and Senegal's l'Institut de Technologie Alimentaire (ITA)** have transferred cereal processing technologies and trained Mbacke and her employees to use them. In addition to employing about 100 women in her processing facility, Mbacke sells her products to women distributors who are part of a nationwide network called the **Groupement d'intérêt économique (GIE)**. GIE distributors buy their products at a discount and sell them for a considerable profit in urban markets, earning income to meet their household needs and to reinvest in their own businesses.

Feed the Future Innovation Lab for Food Processing and Post-Harvest Handling in collaboration with the **Education and Research in Agriculture Project** funded by USAID are partnering with Mbacke to introduce low-cost **extrusion technology**, a precooking process for instant cereal grain products that are shelf-stable, safe and convenient. For the first time, Senegalese consumers will be able to purchase nutritious locally-produced, grain-based instant foods, such as thick porridge *(lakh)*, thin porridge *(rouye)* and weaning foods that are fortified with nutrient-rich local plant concentrates. By adding boiling water to the enriched instant flour, any family member can prepare a nutritious meal, freeing up women for other productive household and business activities.

To increase the production and availability of instant nutritious cereal-based products, a select number of GIE women processors and distributors will be trained in the extrusion technology at Mbacke's facility, and the project is working towards procuring additional low-cost extruders.

A BREXIT FROM INTERNATIONAL DEVELOPMENT?

From 2009 to 2013, the United Kingdom's investment in overseas agricultural development assistance doubled from £92 million to £188 million, but the June 2016 Brexit vote has put the country's current and future international aid commitments in doubt.[24] When the U.K. voted to leave the European Union, the value of the British pound plummeted, effectively cutting the Department for International Development (DfID) budget by £1 billion.[25] Brexit also raises questions about the U.K.'s future contributions to the European Union's development initiatives, causing unease across the Channel. Britain's development community recently expressed concerns about statements from the post-Brexit government indicating an intention to link aid investments to Britain's economic and trade priorities.[26]

SUSTAINABLE DEVELOPMENT IN AN UNCERTAIN SEASON

Political transitions and economic instability are causing governments to tighten their belts, while outbreaks of vector-borne diseases and the migration crisis are straining budgets for development, agriculture and health. The drop in global commodity prices is compelling governments and the agriculture industry to maximize every dollar, making investments in small-scale farmers a potentially high-risk, low-return proposition.

Political and economic uncertainty exacerbates the real and perceived risks for public, private and producer partners collaborating to improve agricultural productivity and nutrition. In this uncertain season, partnerships need to be founded on long-term investments with market-driven solutions. The public sector is responsible for creating a policy environment that stimulates innovation and encourages inclusion and for maintaining a regulatory system that is efficient and consistently enforced. The engagement between the private sector and producer partners must be based on mutual respect, flexibility and transparency.

The role of local leadership in building sustainable and resilient communities should not be overlooked. **Heifer International**, in partnership with **Elanco Animal Health**, increases small-scale livestock production with a program of social capital building, using community Self-Help Groups (SHGs) and farmer cooperatives to train farmers in the care and cultivation of livestock and to support them with access to finance, extension services and markets.

Not only do SHGs stimulate productivity, they can help communities recover from tragedy. In 2008, an earthquake measuring 8.0 on the Richter scale killed nearly 70,000 people in China's Sichuan province and left at least 4.8 million people homeless. To help these communities recover, Heifer started a pig-rearing project in the village of Fuxin in 2011.[27] Within three years, members of the SGH were raising as many as 40 pigs and sows each and want to expand their access to new markets.

When asked what difference the SHG had made in their lives, participants emphasized it had renewed their sense of community. After the earthquake, neighbors greeted each other only in passing, but the Heifer SHGs have formed new bonds between them; group members now eat dinner together and open their homes in hospitality. The SHG is led by a woman named Chang Guifang, whom the community credited with this transformation. "One of the keys to project success is to find a local leader with strong leadership skills," said one observer, adding, "Chang Guifang is one of them."

With rainfall levels 60 to 70 percent below the required volume, millions of farmers in Southern Africa will struggle to harvest a crop in 2016–2017. In July 2016, the **Southern African Development Community (SADC)** launched an **urgent appeal for $2.4 billion in humanitarian aid for 23 million people** who are facing severe food insecurity.[28] The number of hungry people will continue to rise during the lean season (the months between harvests) and so will the need for aid to prevent widespread famine. The current humanitarian crisis requires immediate intervention by donor governments, yet investments to bring tools and strategies to small-scale farmers and rural communities that help them cope with extreme weather events and climate change need to remain a top priority.

Credit: Ann Steensland, GHI

POLICY 5

Expand Regional and Global Agricultural Trade and Harmonize Standards

Improving trade in agriculture and food products is an integral part of meeting global food security needs and the UN Sustainable Development Goals (SDGs).[1] Creating more robust, sustainable agriculture systems requires trade policy frameworks that are forward-looking, innovative and inclusive to benefit producers, consumers and the environment.

A 10 year, $5.4 billion expansion of the Panama Canal will nearly triple the original capacity and facilitate increased trade, allowing ships carrying up to 14,000 containers a quicker path between Asia and the United States.

Improving the trade capacity of low-income countries helps agricultural producers take advantage of market opportunities that will increase their incomes and expand their businesses. On a wider scale, improving trade policies and infrastructure will enable consumers around the world to access a wider variety of foods, as well as staple foods, at competitive prices. Trade will also create employment opportunities along the agricultural value chain and in supporting industries.

With the ability to implement and enforce customs and border regulations, and to build their capacity to export, lower-income countries can add value to their agricultural products while improving productivity and protecting natural resources. For high-income countries with highly productive agriculture systems, trade benefits producers by ensuring their sustainably produced goods reach new global consumers and meet the rising demand for higher quality, more nutritious food, feed, fiber and biofuels.

For societies to benefit from trade, agreements must focus on more than integrating logistics and trade rules. Equally important is the **harmonization of standards, particularly for labor, for food safety and food security, for the environment and for communities** that may not be realizing the full benefits of some trade agreements. Trade agreements need to include investments in social protection and capacity building, as well as ensure that productive resources in agriculture (land, water, forests, wildlife) are sustainably managed and protected.

WHAT IS TRADE POLICY?

Trade policy is made up of rules and regulations that governments put into place to govern movement of goods and services across national borders. Ideally, government policy-makers work unilaterally and in concert with other governments to:

- Reduce tariffs, quota and export taxes;
- Harmonize international standards and greater transparency of sanitary/phytosanitary measures and food labels;
- Protect intellectual property rights;
- Create dispute settlement mechanisms;
- Reduce subsidies;
- Expedite the movement, release and clearance of goods and cooperation between customs authorities (trade facilitation); and
- Support infrastructure development and capacity for trade (transportation routes and storage facilities, export promotion agencies).[2]

This chapter provides examples of how trade facilitation and innovation can benefit food security, livelihoods, public health and the environment, all while meeting regional and global consumer needs for food, feed, fiber and biofuels.

FACILITATING TRADE FOR FOOD SECURITY AND LIVELIHOODS

Fast and efficient customs and port procedures are essential to improving trade and delivering goods and services across borders. Complex processes and documentation raise costs and cause delays, with businesses, economies and consumers bearing the cost. Conversely, countries where inputs can be imported and goods and services can be exported quickly and reliably are more attractive locations for foreign and domestic enterprises seeking to invest.

To address the need for faster and more efficient customs and port procedures, the **World Trade Organization (WTO)**, meeting in Bali, Indonesia in 2013, concluded the negotiations of the **Agreement on Trade Facilitation (TFA)**. The TFA creates binding obligations for WTO members to improve their customs procedures by making them more transparent and efficient, in cooperation with border regulatory agencies and the private sector. It also contains provisions for technical assistance and capacity building to support its implementation in low-income countries.

The TFA plays a key role in helping low- and middle-income countries reduce their trade costs linked to handling imports and exports. **Many of its rules are designed to be beneficial to agricultural businesses, especially small and medium-sized producers**. The TFA also includes a special provision for the expedited **release of perishable goods, helping to reduce post-harvest agriculture losses**.

Reducing global trade costs by 1% = $40 billion increase in worldwide income.

If the TFA is fully implemented, global average trade cost will be **reduced by 10%, resulting in a $400 billion increase in worldwide income,** with most benefit accruing to low- and middle-income countries.[3]

As countries bring the TFA into force, public and private sector investments that improve the national supply chains as well as cross-border management are also generated. These include the development of logistics infrastructures, financing for exporting businesses, helping small and medium enterprises comply with new customs requirements, and logistics for global value chain development. On the import side, the TFA expedites farmer access to inputs like seeds, fertilizers and equipment, as well as to agricultural services and state-of-the-art technology that improve productivity and environmental benefits.

Since many trade facilitation challenges are regional in nature, the implementation of such solutions can boost regional integration and regional trade structures.[4] **Low-income countries in particular will need technical and financial resources and expertise to implement many of these rules and procedures.**

BENCHMARKING TRADE FACILITATION PROGRESS

To help governments improve their border procedures, reduce trade costs, boost trade flows and reap greater benefits from international trade, the **Organization for Economic Cooperation and Development (OECD)** has developed a set of **trade facilitation indicators (TFIs)** that provide a basis for governments to prioritize trade facilitation actions and mobilize technical assistance and capacity-building efforts.

The OECD indicators cover the full spectrum of border procedures for 152 countries across income levels, geographical regions and development stages. By visiting the website and clicking on a country in the world map, information is provided along with reports that benchmark progress in comparison with neighboring countries, regions, and with countries in similar income categories. The website can be accessed at http://www2.compareyourcountry.org/trade-facilitation.

Seeds, Maize and More Without Borders: COMESA Facilitates Regional Trade

Regional economic communities in Africa are developing agricultural commodity and seed standards within each of their membership zones that will eventually be harmonized across the respective regions. The **Common Market for Eastern and Southern Africa (COMESA)** has begun to build its 19 member countries' potential to meet most of the food and agriculture needs of its 500 million inhabitants. But to do this, its farmers must be able to gain better access to improved inputs such as seeds, mechanization and fertilizers, as well as to the technologies and skills to grow and add value to these agricultural goods.

Quality improved seed developed for regional and local conditions gives small and medium-scale farmers the highest return for their investment. In 2013, COMESA countries established a **regional seed release system** to reduce regulatory inconsistencies that have led to artificial barriers to breeding, production and distribution of improved seeds.

Across the COMESA region, **quality improved seed is available to only 1 in 4** smallholder farmers.[5]

The goal of the COMESA harmonization plan is to create by 2020 a vibrant and high-growth seed industry, resulting in improved crop yields for 80 million smallholder farmers in COMESA countries. The plan establishes a common seed catalogue and sets regional rules for seed variety release, seed certification, and sanitary and phytosanitary (SPS) measures to protect people, animals and plants from pests and diseases. COMESA will be able to benefit from the earlier seed harmonization efforts now in place under the Southern African Development Community (SADC) and the East African Community (EAC).[6]

COMESA is also facilitating regional trade in maize, a critically important food security crop for all its member countries. Standards vary across countries: for example, allowable moisture content for imports of maize is set at 13 percent in Tanzania, 13.5 percent in Kenya and 14 percent in Uganda. The tolerance for insect damage is one percent in Uganda, two percent in Kenya and three percent in Tanzania. Without mutual recognition of standards and certificates of analysis, regulatory barriers persist, causing an unpredictable trading environment and costing producers and traders money, as well as contributing to cross-border illegal and informal trade, now estimated at over 80 percent in some COMESA countries.[7]

A **COMESA Mutual Recognition Framework (C-MRF)** signed in 2015 in Kampala, Uganda, has launched a pilot program to standardize testing among six exporting and importing countries (Kenya, Malawi, Rwanda, Uganda, Zambia and Zimbabwe). Among the C-MRF key components are common grading criteria, proficiency testing for aflatoxin (toxic compounds from food mold) and a risk-based sampling protocol.

For small, informal agriculture producers who wish to take advantage of cross-border opportunities, COMESA is rolling out streamlined rules to reduce complicated customs certificates. Trade ministers have endorsed a new **simplified trade regime (STR)** that offers certificates of origin that enable small producers and traders to access duty and quota free trade as long as their goods appear on a list of agreed-upon products that currently incudes tea, coffee, maize, wheat, sorghum, sisal, fish and raw milk. Available only to small-scale border traders with consignments valued at $500 or less, the certificates will be filled in by traders at designated border posts and stamped by customs officials upon verification.

SPOTLIGHT ON TRADE: LATIN AMERICA AND THE CARIBBEAN

The **Latin American and Caribbean Region (LAC)** is an agricultural powerhouse that is becoming a regional and global breadbasket. Yet the **Inter-American Development Bank (IDB)** found that the typical LAC country has fewer agricultural value chain linkages than most countries in Asia or Europe. Creating an enabling environment for the development of regional and global value chains is a priority and trade facilitation reform is a vital first step.

Reducing supply chain barriers and facilitating trade in the LAC region could potentially boost exports by up to 38 percent for some countries and GDP by up to 8 percent.[8]

The following cases illustrate how regional partners in LAC are advancing better trade systems for livelihoods, food security and for consumer food safety.

Harmonizing Trade for Food Safety

The **Inter-American Institute for Cooperation in Agriculture (IICA)** is the specialized agency of the Inter-American System for agriculture, with 34 member states across the Western Hemisphere. IICA, in partnership with other regional institutions such as the IDB and with the **U.S. Department of Agriculture (USDA)** and **U.S. Agency for International Development (USAID)**, invests in institutional, human, financial and technological resources to build member countries' capacities to harness the power of trade.

The ***Codex Alimentarius***, or the food code, is a collection of internationally recognized standards, codes of practice, guidelines and other recommendations relating to foods, food production and food safety. *Codex* plays a key role in world trade and in the protection of consumers' lives and health, as standards are based on the best available science. The ***Codex Alimentarius Commission*** is a joint body of the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) with goals of protecting the health of consumers and of ensuring fair practices in international food trade.

A growing number of low-income countries are taking an active part in the *Codex* process and are participating in Commission meetings in order to compete in sophisticated world markets and improve food safety for their own populations. Governments see benefits for health and trade in implementing *Codex* standards, and farmers who follow them know that their produce can be sold at home and abroad. Compliance by exporters ensures that consumers can trust the safety and quality of foods, and traders are protected from losing money from substandard shipments.

Guyana food safety sector professionals participate in a technical workshop aimed at increasing capacity for strengthening the functioning of the *Codex Alimentarius* structure in Guyana. The project, led by Chile, IICA and USDA, achieves stronger *Codex* systems, not only in Guyana, but also in Jamaica, Trinidad and Tobago, Saint Lucia and Suriname.

Credit: IICA

In 2009, IICA formed a partnership with USDA to implement a long term plan to build capacities of Latin American and Caribbean countries to participate in *Codex* processes and effectively harness agricultural and food trade. Through IICA's **Agricultural Health and Food Safety Program (AHFS Program)**, countries gain a better understanding of the multiple and complex *Codex* committees so they can participate in and make better use of opportunities for engagement.

The program has enabled countries to promote standards of national or regional interest, defend their positions and improve their national policy and technical structures. This has resulted in substantial improvements in the capacity of LAC countries to take advantage of *Codex*, ensuring that the region is more united and informed on trade matters, and that their efforts to improve agricultural trade among themselves and with other regions are better coordinated.

PROTECTING CONSUMERS FROM FOOD BORNE ILLNESS

As global food trade increases, governments need food safety and inspection systems to protect consumers from food-borne illnesses. According to data from the **U.S. Food and Drug Administration (FDA)**, each year more than 360,000 illnesses related to agricultural products are diagnosed in the United States. The U.S. **Food Safety Modernization Act (FSMA)** takes a preventative approach to food safety. It requires U.S. importers to ensure that their foreign suppliers can meet the same safety standards for food produced domestically.

The FDA works with governments, universities and multilateral organizations to educate exporters about the safety requirements they will have to meet to market agricultural products in the U.S. In Latin America and the Caribbean, food safety specialists from **IICA**, the **International Center for Food Industry Excellence (ICFIE) at Texas Tech University (TTU)**, trade specialists from **USDA Foreign Agricultural Service** and the FDA conducted capacity building activities in several countries. This initiative included 14 workshops targeting more than 1,500 participants responsible for export from countries across the region, with the goal of improving their capacity to comply with the new rules.

Ongoing capacity development initiatives at regional and local levels will continue to inform exporters and producers about FSMA rules in areas such as preventive control for human and animal food and feed facilities, foreign supplier verification programs and third party accreditation rules. These efforts are also producing and disseminating user-friendly training manuals for hygiene practices during growing and harvesting, as well as safety tips for chemical handling. Collaboration with local governments, export entities and private trade groups will ensure effective training and compliance across the food production value chains.

How Sweet It Is!
Jamaica Develops a Commercial Sweet Potato Industry

In 2014, **IICA** responded to a request from the **Jamaica Ministry of Agriculture and Fisheries (MoAF)** for technical assistance to bring up to 2,000 acres of land into production for orange flesh sweet potato. The MoAF wanted to take advantage of the growing demand for orange flesh sweet potato in Europe and Canada to help Jamaican farmers improve their livelihoods, while contributing to country's GDP through foreign exchange earnings.

The first task for IICA was to determine which varieties of sweet potatoes could be produced commercially in Jamaica, as well as a developing an export-oriented post-harvest handling system that preserved the quality and nutrient content of the product. IICA enlisted two U.S. land-grant universities to provide technical assistance and capacity building in commercial sweet potato production.

North Carolina State University (NCSU) provided technical assistance in the propagating, harvesting and handling the Beauregard and Covington sweet potato varieties. The Jamaica MoAF established the Sweet Potato Clean Seed Program and acquired a two-year license to test the performance of the Covington sweet potato variety under Jamaican conditions — the first and only government institution in the Caribbean and Latin America to do so. With NCSU sharing its knowledge and connections to the U.S. sweet potato industry, Jamaica became an associate member of the North Carolina Potato Commission and organized a trade mission to the Annual National Sweet Potato Convention.

In 2015, the MoAF received an order for 2.4 million pounds of Beauregard sweet potatoes from the U.K. market. **Louisiana State University (LSU)** was brought in to help train farmers and extension officers in commercial Beauregard production and handling. Beauregard "foundation seed" was purchased from the LSU AgCenter which the MoAF used to propagate virus-free planting material for sale to farmers. MoAF and private industry officials toured sweet potato curing, storing and processing facilities for value-added products in Louisiana.

Jamaica is now harnessing the power of trade to produce commercial sweet potato products for the first time, providing nutritious foods for growing regional and global demand.

Thanks to the collaboration with IICA and the partnerships to build technical capacity, Jamaica is now producing commercial sweet potato products for the first time, opening up new markets for farmers, building the economy and increasing the production of a high-demand, nutrient dense, value added food.

KEEPING LABOR AND THE ENVIRONMENT IN FOCUS

Bilateral or smaller regional free trade agreements (FTAs) provide economic benefits but they often have little influence on standards covering labor, environment and best business practices. With the global Doha Round of the World Trade Organization (WTO) talks currently stalled, the prospect of developing more deeply integrated regional agreements are being explored, such as the **Trans-Pacific Partnership (TPP)**.

The TPP is a regional trade agreement among 12 countries that account for 36 percent of the world's GDP. The countries are centered primarily in the Asia and Pacific Rim region, with a range of per capita incomes and varied economic systems. The agreement aims to eliminate more than 18,000 tariffs and establishes a shared approach to intellectual property, labor and environmental laws.

Strong economic benefits are expected to accrue from implementing the TPP. **By 2030, the increase in annual real incomes from the TPP in the U.S.** alone will be **$131 billion; U.S. exports**, much of which will be agricultural goods, will **increase by $357 billion. Annual income gained globally by 2030 will be $492 billion.**[9]

Concerns have been raised about whether the TPP can also deliver environmental and labor benefits, and what support will be available for workers who may be displaced by such a large-scale trade agreement.

Analysis of the TPP by the U.S. International Trade Commission indicates the agreement has the potential to encourage improvements on the environment and labor fronts.[10] In particular, the agreement enhances the abilities of countries to **enforce laws against wildlife trafficking and will help prevent trade in fish products from illegal, unreported and unregulated (IUU) fishing sources**.[11] For instance, Japan and the United States are top fish importers, while Vietnam, Chile and Canada are major fish exporters; as participants in the TPP, all parties would be subject to enhanced, enforceable regulations covering IUU fishing sources. By using tracing methods, fish can be tracked through regional supply chains for compliance.

The TPP would also **improve global efforts to abolish child labor and gender discrimination**, present in agriculture production systems throughout several TPP countries, and **protect collective bargaining**, a significant protection for labor that is not available in existing trade agreements.[12] On the energy front, TPP will boost the adoption of more clean energy by **cutting tariffs on renewable energy technologies** and helping signatory countries shift to renewable energy products. TPP eliminates taxes on wind turbines and solar panels and will increase the production and export of biofuels.[13]

The purchasing power of today's U.S. consumer serves as an incentive for TPP signatory nations to improve their practices and conduct in agriculture, trade, services and manufacturing. If ratified, the TPP would bring enforceable, more progressive standards of conduct for labor and the environment, and boost economic growth of the parties and the wider global economy.

On the whole, trade agreements are a net positive for the economy, but for some people, shifts in production patterns could mean a job loss or a reduction in wages. Governments have a responsibility to make significant, strategic and long-term investments in the people and communities that are negatively impacted by trade agreements, by retraining workers and supporting the development of new industries, particularly in rural areas where there are fewer employment options. Social protection programs assist workers who have lost or may lose their jobs as a result of foreign trade and provide opportunities to obtain the training and new skills necessary for reemployment. In the United States, the federal government's **Trade Adjustment Assistance Program (TAA)**, has provided such support to 2 million U.S. workers affected by trade since 1975.

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A pearl millet farmer with part of her harvest.
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