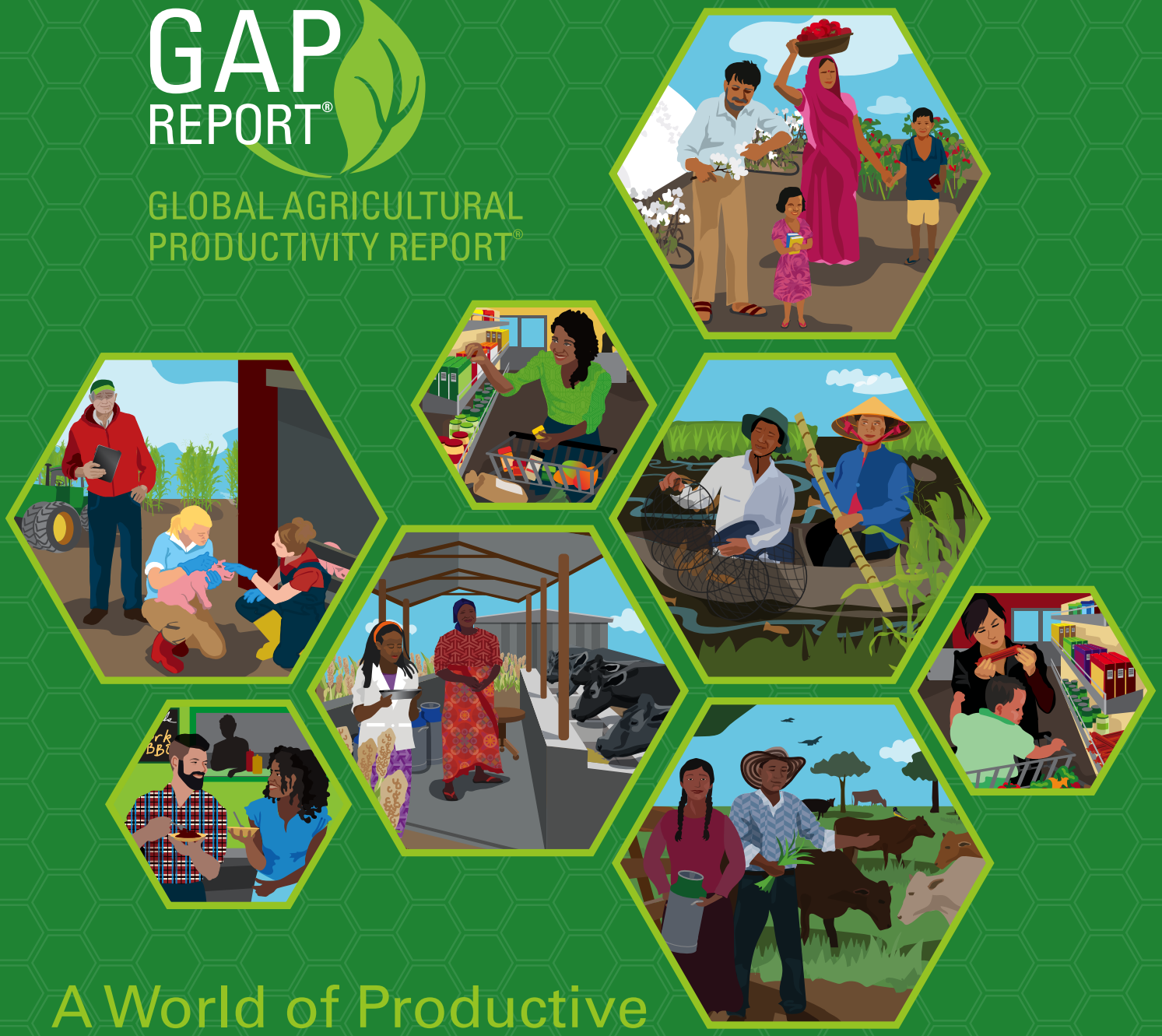
2017 GAP REPORT®

GLOBAL AGRICULTURAL PRODUCTIVITY REPORT®



A World of Productive Sustainable Agriculture

GLOBAL HARVEST INITIATIVE

2017 Global Agricultural Productivity Report® (GAP Report®)
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This report is dedicated to **William "Bill" Lesher,** the founding Executive Director of GHI and driving force behind the creation of the GAP Report®, who passed away earlier this year.

GLOBAL HARVEST INITIATIVE

Global Harvest Initiative (GHI) was formed in 2009 as a private-sector policy voice for increasing the productivity and sustainability throughout agricultural value chains for food, feed, fiber and biofuel. We believe the right policies, practices and technologies improve global food security and nutrition, 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 livelihoods for producers and strengthening the resilience of food and agriculture systems.

GHI's member companies are DuPont, Elanco Animal Health, Farmland Partners Inc., John Deere, Monsanto Company, The Mosaic Company and Smithfield Foods.

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LETTER FROM THE EXECUTIVE DIRECTOR

A World of Productive Sustainable Agriculture

In 2050, the number of people living on our planet will grow to almost 10 billion, with billions joining the middle class and living in urban areas. Our growing world will require more food, feed, fiber and biofuels, nearly doubling the demand from 2005 levels.

Our imperative is to work with the world's farmers and agricultural systems to meet this increasing demand in ways that are economically viable, environmentally sustainable and socially beneficial.

Farmers everywhere face considerable challenges. Volatile business cycles make it difficult for them to manage risk and to invest for the future. In some regions, conflict and natural disasters disrupt agricultural production and generate famine and human suffering. Climate change exacerbates extreme weather events that destroy farmer livelihoods.

Yet farmers understand these challenges and have remarkable capacity to innovate as they consider what and how much to grow, how to cultivate, when to sell and where to invest. They also have enormous potential for coping with risks like weather volatility and market and political uncertainty. What they need are supportive systems, policies and investments that foster thriving, sustainable enterprises.

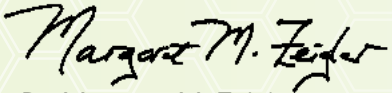
The 2017 Global Agricultural Productivity Report® (GAP Report®) explores the diversity of challenges farmers around the world face and how they seek to surmount them.

The report also reveals how producers and consumers are united by a desire for food and agriculture products that are safe, nutritious and affordable, and are produced in ways that deliver economic, health and environmental benefits for families and communities.

Agricultural productivity is an essential component of sustainable food and agriculture systems. GHI's annual **Global Agricultural Productivity (GAP) Index™** reveals that, for the fourth straight year, global agricultural productivity growth is not accelerating quickly enough to sustainably meet the demands of our growing world. Perhaps most troubling is the continued decline of agricultural productivity growth in low-income countries.

Throughout the GAP Report®, we identify the strategies, policies and investments needed for improving the productivity and sustainability of agriculture and the benefits they bring to consumers and producers.

The challenges we face are formidable, but our goals are within reach. We hope this report adds insights on how to achieve them.



Dr. Margaret M. Zeigler
Executive Director
Global Harvest Initiative

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UNITED STATES

From 2017 to 2026, **global commodity prices will remain relatively low,** making it difficult for U.S. farmers to stay competitive.[2] Doubts about **regional and global trade opportunities** and the need for further public and private investments in **agricultural research and development** create uncertainty for farmers, who require cutting-edge innovations that improve productivity and promote sustainability. A **lack of broadband internet service** across 40 percent of rural America limits many farmers' access to precision agriculture.[3] Every hour, another 40 acres of productive farm and ranchland are lost to urban sprawl and development, **keeping land prices high** and posing a barrier for young people to enter farming and replace an aging farmer population.[4]

The Global Agricultural Sustainability Imperative

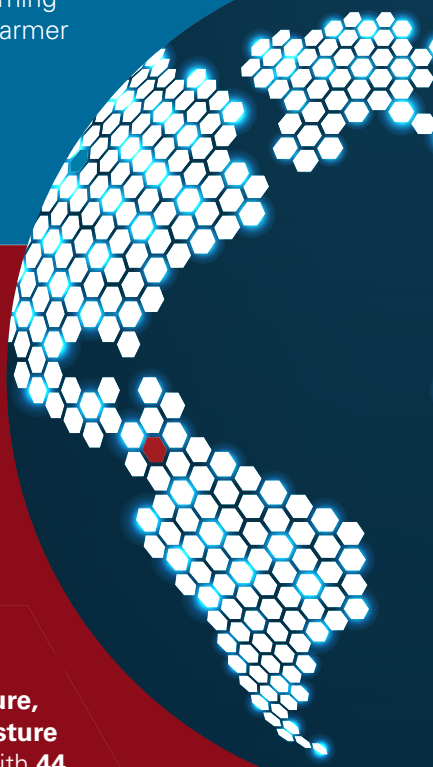
In 2050, the number of people living on our planet will grow to 10 billion, and that could double the demand for food, feed, fiber and biofuels from 2005 levels.[1] It is imperative that this demand be met in a way that is economically viable, environmentally sustainable and socially beneficial.

In light of this, our food and agriculture systems face enormous challenges. **Climate change** threatens agricultural productivity. **Volatile agricultural business cycles** make it difficult for farmers to manage risk and invest for the future. **Conflict and migration** generate famine and human suffering. And **global health is compromised** by malnutrition, poor diets and disease.

The 2017 GAP Report illuminates the many ways farmers and consumers around the world experience the imperative for sustainable agriculture, and how they are attempting to meet the challenge.

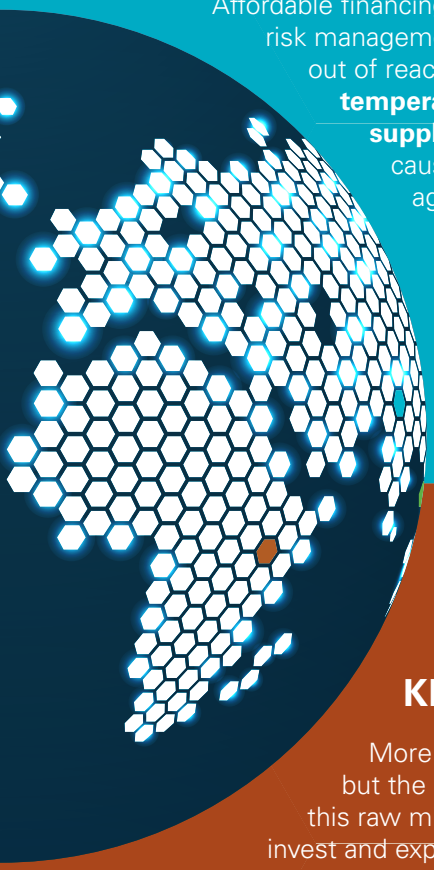
COLOMBIA

With the end of the 50-year civil war in Colombia, a new era of peace is giving rise to opportunity in the agriculture sector, which will play a key role in future growth and prosperity. **Of the total land area used for agriculture, 80 percent is used for livestock pasture and 19 percent for other crops,** with **44 percent of rural agricultural producers living in poverty.**[5] The potential for increasing their resilience and incomes relies heavily on targeted investments in research, extension and partnerships.



INDIA

India will overtake China as the **world's most populous country** in the next few years. Its agriculture sector is **dominated by 120 million small-scale farms** (less than two hectares), which hampers widespread adoption of technologies and practices to improve productivity and sustainability.[6] Affordable financing from formal lenders and risk management tools like insurance are out of reach for most farmers. **Rising temperatures and unreliable water supplies** due to climate change will cause significant hardship for agricultural producers.



VIETNAM

Rising sea levels are increasing the salinity of the Mekong Delta, threatening rice and aquaculture production in Vietnam's rice bowl region. Farmers need support to diversify their crops and add more value to them. **Investment rates in public agricultural R&D and extension are extremely low** and must increase to help farmers modernize for the future. Partnerships with the private sector are taking root to establish productive agricultural value chains but require ongoing attention to environmental sustainability.

KENYA

More than one million small-scale farmers earn income from milk production, but the **average milk output per cow is only 1.8 gallons per day.**[7] Most of this raw milk is consumed or sold at low prices, making it difficult for farmers to invest and expand their operations. Rain-fed agriculture accounts for 70 percent of employment across Africa[8], and without better access to improved seeds and fertilizer, **drought will drive more farmers into hunger and poverty.** Clashes **between herders and farmers will increase** as competition for land intensifies.

CONSUMERS

As population and incomes rise around the world, so does the demand for livestock products and other high-value foods. A growing number of consumers want to **ensure their food is sustainably produced** and many are concerned about the **safety, price and availability of nutritious food.** Two billion people have micronutrient deficiencies, 159 million are stunted and 43 million are overweight. Malnutrition is the underlying cause of 45 percent of deaths of children under five years old, while as many as 70 million children may be overweight or obese by 2050.[9]

Sustainable Agriculture Is Possible

WHAT IS SUSTAINABLE AGRICULTURE?

Sustainable agriculture must satisfy human needs; enhance environmental quality and the natural resource base; sustain the economic vitality of food and agriculture systems and improve the quality of life for farmers, ranchers, forest managers, fishers, agricultural workers and society as a whole.[10]

Improving agricultural sustainability requires multi-faceted, collaborative solutions involving producers, agribusinesses, transporters, retailers and policymakers.

The 2017 GAP Report® describes the critical role productivity plays in sustainable food and agriculture systems (pages 8–17) and puts a human face on this complex challenge through stories from the U.S., India, Kenya, Vietnam and Colombia (pages 18–66).

Satisfies human needs

Improves the lives of agricultural producers and society as a whole

Enhances environmental quality and the natural resource base

Sustains the economic vitality of food and agriculture systems

Agriculture and the Sustainable Development Goals

The United Nations Sustainable Development Goals (SDGs) establish targets for achieving inclusive economic growth, social development and natural resource conservation and biodiversity by 2030. The SDGs recognize the interconnectedness of the global community — its people, its economies and the environment.

Sustainable agriculture practices and technologies contribute to many of the 17 SDGs by helping to end hunger and malnutrition, reducing postharvest loss and food waste, mitigating climate change, providing clean sources of energy, preserving biodiversity, reducing poverty and promoting good health, gender equality and education.

Satisfies Human Needs

The SDGs call for an end to hunger and malnutrition, with an emphasis on doubling the productivity of small-scale producers who are more likely to be net food buyers, living in poverty and struggling with malnutrition. Reducing postharvest losses and food waste through responsible consumption will increase the amount of nutritious food available for farmers and consumers, while lowering environmental impacts.

Sustains the Economic Vitality of Agriculture

Drought-tolerant and pest-resistant seeds, mechanization and healthy livestock enable farmers to produce more output while reducing their input costs, thereby increasing their incomes. Affordable financing and weather index insurance give farmers the confidence to grow their operations by protecting their capital assets when crops fail. Value-added agricultural production and trade stimulate the economy and create jobs.

Enhances Environmental Quality and the Natural Resource Base

Agriculture can mitigate climate change. By improving soil, nutrient and water management practices, increasing livestock productivity and promoting biodiversity through mixed cropping systems and agroforestry, producers can supply food while also reducing greenhouse gas emissions.

Improves the Quality of Life for Agricultural Producers and Society as a Whole

Increased agricultural productivity and incomes enable small-scale farmers to send their children to school. Innovation improves the lives of women farmers and co-operatives empower women to become entrepreneurs in the agricultural value chain. As agricultural incomes grow, communities invest in clean water and sanitation.

Sustainable Agriculture Is Built on Productivity

The United Nations defines sustainable growth as, "meeting the needs of the present without compromising the ability of future generations to meet their own needs." No one understands this delicate balancing act better than farmers, ranchers, forest managers and fishers.

Do I plant to the edge of my property to earn more during this season of low crop prices? Or do I place more erodible land in conservation, preserving the health of my soil for the future?

Do I adopt unfamiliar cultivation practices that will help me adapt to climate change even though it will require additional labor for a few years?

Do I buy more livestock to increase my output? Or do I invest in better feed and veterinary services to improve the productivity and health of my current herd?

Do I invest in capital improvements like a tractor or more land that I can pass on to the next generation? Or do I rent them and keep my farm competitive today?

As they balance the demands of the present with the needs of the future, producers decide how much risk they are willing to take. They must consider the risk-management options available to them, as well as factors they cannot control like weather, market prices and economic or political uncertainty.

While trade-offs are inevitable, **policies and investments that support agricultural productivity and expand risk management capacity give producers the best chance to meet current and future needs,** while increasing their adaptability and resilience.

STRATEGIES FOR MEETING AGRICULTURAL DEMAND

There are multiple approaches to meeting the current and future demand for agricultural products.

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

» **Irrigation** — Producers deploy or extend irrigation systems to protect land against drought and improve its productive capacity, which may permit multiple cropping seasons. If not carefully managed, groundwater may be depleted.

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

Meeting demand in a way that reflects the needs of producers and consumers today, while safeguarding our future agricultural capacity, is best achieved another way:

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

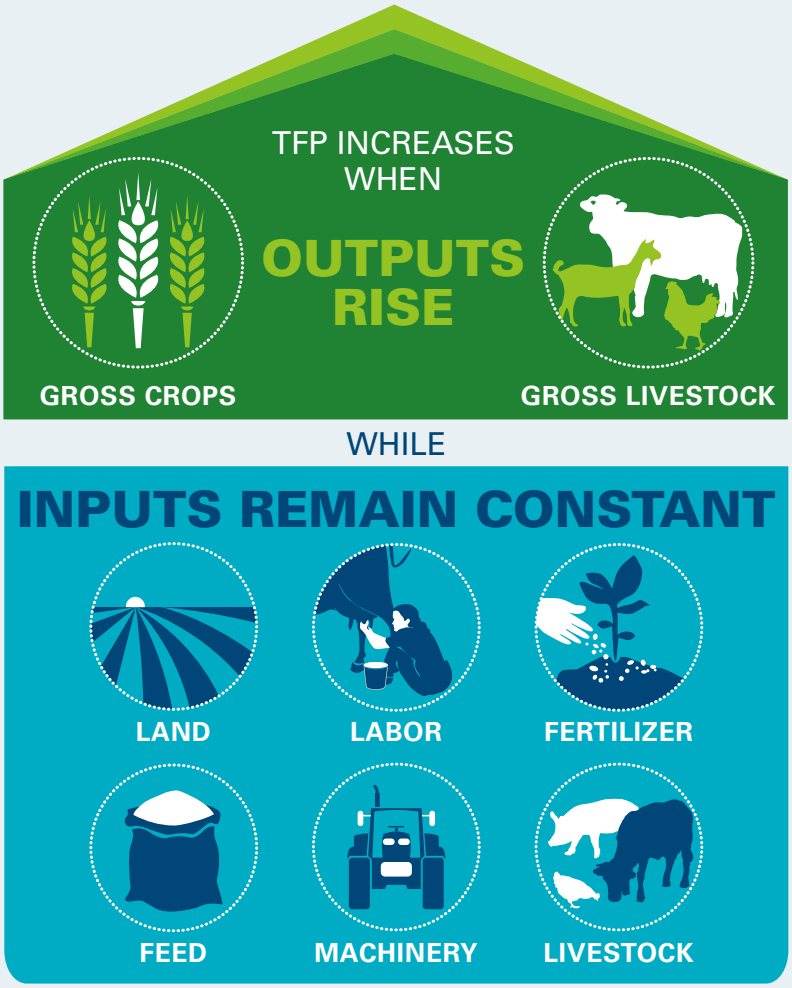
WHAT IS PRODUCTIVITY IN AGRICULTURE?

Agricultural productivity is distinct from output, which refers to the gross amount produced, or yield, which measures the amount of output per unit of production, usually land.

TFP (Figure 1) 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 these inputs are transformed into outputs.**

By measuring TFP, as opposed to yields or output, we understand the extent to which increased output is due to better use of these critical resources. **Policymakers, development agencies, researchers and producers use TFP to identify where improvements are needed** in agricultural production systems and to determine which investments and policies increase productivity and enhance sustainability.

Figure 1: Total Factor Productivity



PRODUCTIVITY PROMOTES COMPETITIVENESS AND CONSERVATION

TFP looks beyond how much we are producing. It reveals how efficiently we are producing it and indicates how well we are conserving available resources to meet our future needs.

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 lower prices for consumers. Farmers use productive technologies and practices such as improved seeds and farm equipment, genetically improved livestock and good animal husbandry to increase output while conserving land and water and protecting soils for future generations.

In addition to promoting competitiveness and conservation, **productive technologies and good practices also support the SDG goals** to end hunger and malnutrition, protect the safety of the water supply and reduce greenhouse gas emissions.

Case studies throughout the 2017 GAP Report® demonstrate how farmers of all scales, producing a variety of products in different geographies, are conserving and protecting their soil and water resources while reducing their climate impact.

Some of the innovations highlighted in the 2017 GAP Report® include drought-tolerant seeds that enable poor farmers in dryland areas to grow in stressful conditions; precision agriculture technologies that enrich soil in the field and keep nutrients out of streams; and animal care innovations and practices that improve the health and productivity of each animal while reducing emissions from livestock production.

Productivity on the Rise, With Room to Grow

TFP accounts for the largest share of growth in global agricultural output today (Figure 2). In the 1960s, the Green Revolution introduced high-yielding seeds to millions of farmers, along with access to fertilizers, irrigation and machinery. As farmers began to use those inputs more efficiently, the contribution of inputs per land area to agriculture output declined (orange bar) and TFP's contribution increased (green bar).

Low-income countries have mirrored the global trend in TFP growth and enjoyed a substantial increase in agricultural output (Figure 3). However, since the 1980s, opening new land for agricultural production (red bar) remains the primary driver of agricultural output. Economic and political forces have driven land expansion in low-income countries: transitions to market-based economies, the introduction of input subsidies and prices supports, growing populations needing more land to cultivate and the extension of irrigation. While some land is suitable for agricultural expansion, **greater productivity on existing cultivated land needs to be prioritized to minimize agriculture's impact on soil, water, forests and wildlife.**

Low labor productivity on small-scale farms, predominantly found in low-income country agricultural systems, largely accounts for the higher inputs per hectare of agricultural land results (Figure 3, orange bar). Small-scale farms are labor-intensive due to insufficient off-farm or urban employment opportunities that could absorb the excess labor in rural areas. Small-scale farmers also struggle to purchase or rent machinery at competitive prices relative to their labor cost. This contributes to high rates of rural poverty and food insecurity.

In **high-income countries,** all growth in agricultural output is now generated by TFP, while the amount of inputs per hectare of land has declined and **land and labor have been taken out of agricultural production** and put into conservation or to other productive uses (Figure 4). Technologies such as pest-resistant high-yielding seeds, precision agriculture machinery systems and improved animal care and production practices enable farmers to increase their output while controlling costs, conserving land and water resources and reducing the environmental footprint of agriculture.

Nevertheless, **TFP growth has slowed** in high income countries (Figure 4, green bar). Future TFP growth will be driven by innovations such as advanced crop and livestock breeding and data systems that monitor plant growth and animal health. However, public-sector investments in the research and development (R&D) that drive agricultural innovation has slowed in many high-income countries.

Public R&D provides discoveries that are the foundation for further private-sector innovation; lower public investments constrict the innovation pipeline. Private-sector research investments, while significant, cannot make up the public R&D funding gap. **Increased public-sector R&D investments are needed to reinvigorate productivity growth.**

Additionally, as urbanization increases, so does **competition for land and water resources.** Continued farm consolidation will create some additional efficiencies, but land and water-use policies must balance the resource needs of agricultural producers with those of their urban customers.

REDUCING RISK AND WASTE

Productivity alone is insufficient to achieve economically, environmentally and socially sustainable food and agriculture systems. **Food and agriculture systems are vulnerable to a variety of risks,** including extreme weather events and climate change, market volatility and political instability. During times of crisis, agricultural producers seek to minimize their losses without putting their future productivity at risk. Good innovations and an enabling policy environment can ensure they stay productive during seasons of risk. This also helps stabilize the supply and price of food and agriculture products.

Public and private insurance programs, such as crop insurance or weather index insurance, help preserve producer incomes and enable them to keep their most productive assets. Some producers participate in conservation programs that reward them for protecting their soil and water resources.

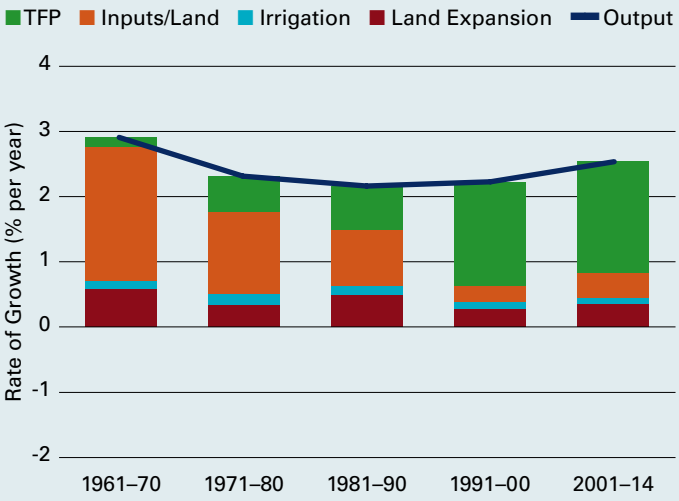
Those without access to insurance and conservation programs face difficult choices. During hard times, small-scale farmers usually raise cash by selling cattle and equipment or by leasing their land; the poorest farmers have little to sell, so they reduce their consumption of food and may resort to pulling children from school and into labor. These coping strategies have generational impacts on the health and economic prospects of the family as well as their farm operations.

Consumers also face risks from economic instability or food price shocks. Governments are establishing social protection programs to stabilize households experiencing food and income insecurity. Some countries rely on national reserves to feed their population and manage food prices. Ensuring that agricultural trade remains open

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

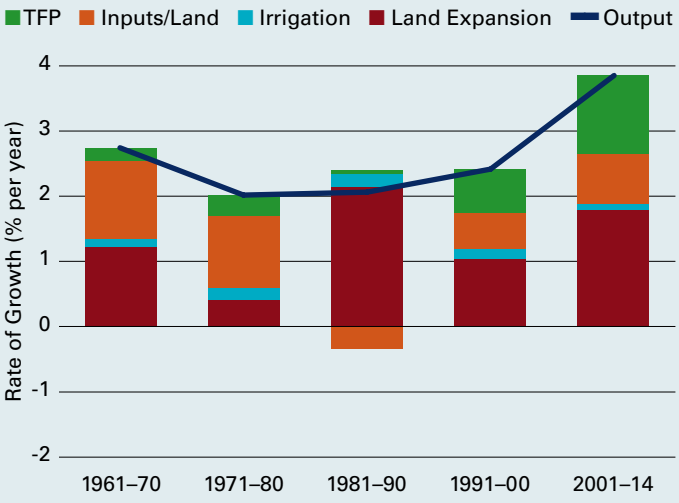
- **TFP** — Gross amount of crop and livestock outputs per inputs (labor, capital and materials)
- **Inputs/Land** — Gross amount of fertilizer, machinery, feed, labor and other inputs per hectare of agricultural land
- **Irrigation** — Extension of irrigation to agricultural land (which raises the number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

Figure 2: Sources of Growth in **Global** Agricultural Output, 1961–2014



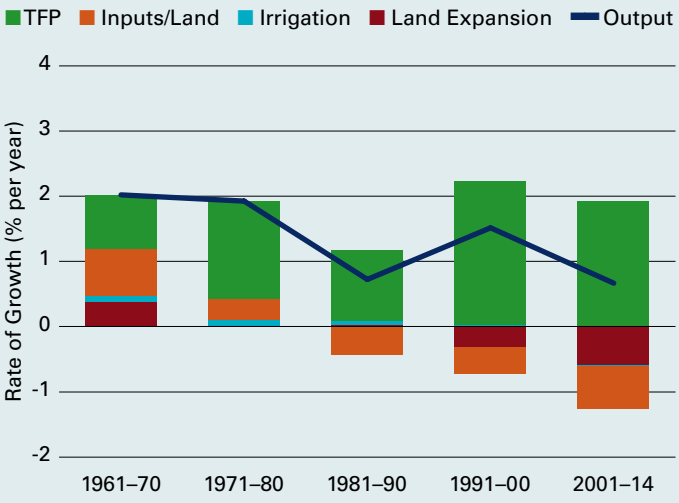
Source: USDA Economic Research Service (2017).

Figure 3: Sources of Growth in Agricultural Output: **Low-Income** Countries, 1961–2014



Source: USDA Economic Research Service (2017).

Figure 4: Sources of Growth in Agricultural Output: **High-Income** Countries, 1961–2014



Source: USDA Economic Research Service (2017).

is essential to keeping food prices stable, especially when commodity stocks are low.

Reducing agricultural losses on the farm and food lost throughout the agricultural value chain avoids wasted resources and unnecessary greenhouse gas emissions. Improvements must be targeted throughout every part of the value chain: better harvesting and storage practices, better livestock care to reduce disease, improvements to the cold chain and the transportation infrastructure it relies on, reductions in waste at the processing and retail levels and changes in consumer behavior. Reducing loss and waste on a wide scale depends on government investments in public goods, such as infrastructure. An enabling policy environment that supports private-sector innovation in harvest and storage technologies and stimulates behavior change by consumers is also vital.

In addition, there are opportunities to increase the productive use of unconsumed food and agricultural byproducts. These are potential sources of bio-energy, animal feed, fertilizer and new products. Reducing loss and waste and creating more opportunities to use waste productively will help meet the growing global demand for agricultural products, generate clean energy, mitigate carbon emission, create new jobs and industries and improve incomes and food security, especially for small-scale producers.

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 to nearly double agricultural output *through productivity* by 2050.

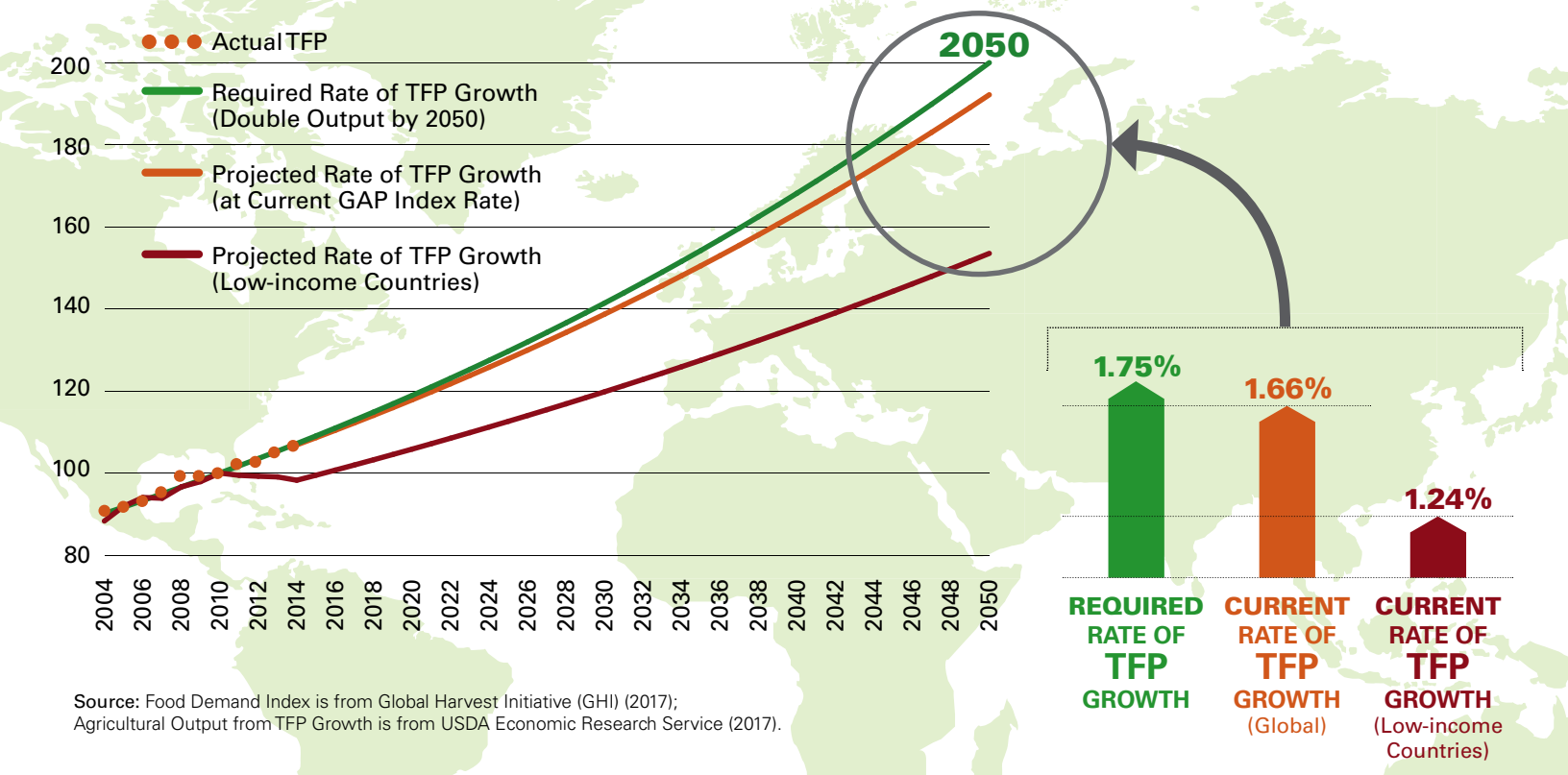
The 2017 GAP Index™ reveals that **for the fourth straight year global TFP growth is not accelerating fast enough** to sustainably double agricultural output by 2050. The U.S. Department of Agriculture's Economic Research Service (USDA ERS) estimates that since 2004, TFP growth globally has been rising by an **average annual rate of only 1.66 percent.**

While the global growth rate is close to the target, the **TFP growth rate in low-income countries continues to decline,** as tracked by the GAP Index™ from 1.5 percent (2015) to 1.31 percent (2016) to 1.24 percent (2017).[11] **This is well below the TFP growth rates needed to achieve the SDG 2 target of doubling productivity for small-scale farmers** in the lowest-income countries by 2030.

If this trend continues, farmers in low-income, food-deficit countries (where population growth is rapidly rising) will use more land and water to increase their output, straining a natural resource base already threatened by extreme weather events and climate change.

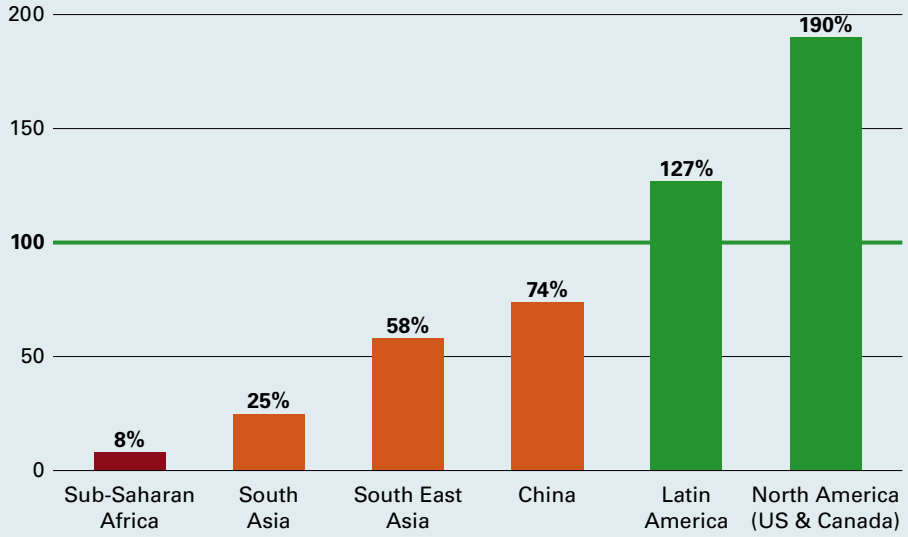
Many low-income countries will need to import food but lack sufficient income to purchase enough to meet the needs of their citizens. Poor urban households will bear the brunt of higher food prices in these countries, but they will also impact low-income rural populations since they are net food buyers. Some of the food demand will not be met and millions of people will be debilitated by hunger and malnutrition.

THE GLOBAL AGRICULTURAL PRODUCTIVITY (GAP) INDEX™



Source: Food Demand Index is from Global Harvest Initiative (GHI) (2017); Agricultural Output from TFP Growth is from USDA Economic Research Service (2017).

Figure 5: Percent of Food Demand Met Through Productivity (TFP) Growth in 2030



Source: Food Demand Index is from Global Harvest Initiative (2017).
Agricultural Output from TFP is from USDA Economic Research Service (2017).

Note on methodology: The projection of agricultural output from TFP growth uses USDA ERS (2017) estimates of average TFP growth during 2004–2014 and assumes this is maintained through 2030. The projected growth in food demand uses UN estimates of population, World Bank estimates of GDP forecasts and PricewaterhouseCoopers LLP (PwC) estimates of GDP growth in PPP, 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.

REGIONAL TFP GROWTH RATES RAISE CONCERNS

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. Figure 5 compares the percentage of the estimated food demand for 2030 that can be met with projected TFP growth for six world regions and China.

At current rates of TFP growth, sub-Saharan Africa (SSA) will meet only 8 percent of its food demand through productivity. This is almost 50 percent lower than the 2014 projection of 15 percent, a troublesome trend. Trade plays a key role in closing Africa's food demand gap; 50 percent of its vegetable oils, 35 percent of its poultry meat and 23 percent of its sugar requirements are imported.[12]

Without significant increases in agricultural productivity growth, African countries will not meet their SDG targets for reducing hunger, malnutrition and poverty.

With 60 percent of the world's population and considerable economic diversity, the **Asian regions** (South Asia, South East Asia, East Asia, including China) exhibit varying degrees of capacity to meet food demand through productivity.

China has prioritized agricultural development and food security and has achieved great progress in reducing hunger. Yet with little arable land and growing affluence, China will require more investments in productivity and more trade to meet future demand.

Other Asian countries, such as **India, Indonesia and Vietnam,** could potentially reduce hunger and improve agricultural productivity, but face significant threats from climate change, requiring accelerated investments to keep up with the challenge.

Latin America (LAC) continues to position itself as a rising global breadbasket. At present TFP growth rates, LAC will be able to meet 127 percent of regional food demand through productivity growth, an increase of 11 percentage points since 2014.

The LAC region and particularly the southern cone nations of Argentina, Brazil, Paraguay and Uruguay comprise the world's largest net exporting zone of agriculture products.[13] 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.

Harmonizing trade rules and improving the trade capacity of low-income countries, coupled with improvements in supply chains and infrastructure, will foster timely and beneficial trade to close food and agriculture demand gaps.

In 2030, **North America** is projected to reliably supply safe, abundant food for the world, producing 190 percent of its own food demand. However, the potential for a new era of trade protectionism has sent a chill through agricultural producers who fear they will lose access to traditional trade partners or fail to access new markets at a time when prices are low and farmers are struggling.

HOW WILL WE MEET FUTURE DEMAND?

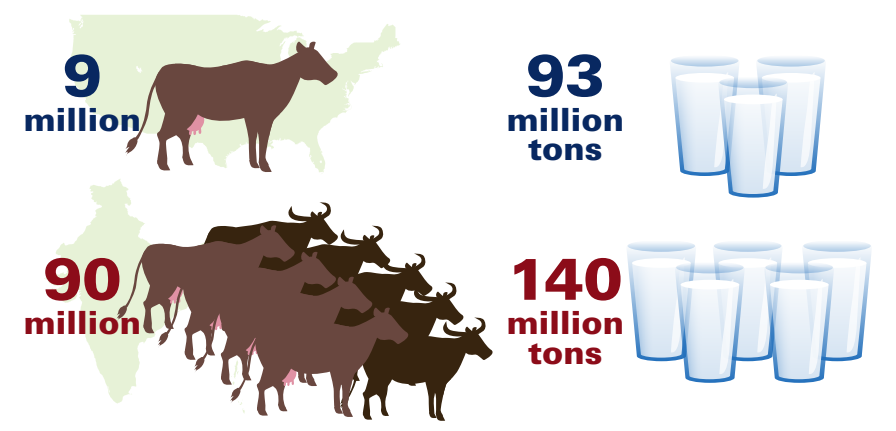
The previous 10 years have witnessed unprecedented demand for agricultural commodities, driven by income increases and population growth in China and India, as well as demand for biofuels stimulated by high energy prices.

Over the next decade, the OECD and the United Nations Food and Agriculture Organization (FAO) project that the rate of demand growth for all agricultural commodities will slow compared with the last decade. The rate of demand growth for cereal grains, meat, fish and vegetable oil will be cut nearly in half, the notable exception being increasing demand for fresh dairy.[15] OECD and FAO attribute the decline in the rate of demand growth to moderating rates of economic growth, particularly in China, and a decline in demand for biofuels.

While the *rate of demand growth* may be slowing (compared to the previous 10 years), the **overall demand for food and agriculture products is still rising,** as is the global population. In fact, **the highest demand growth for many agricultural products is coming from regions with high rates of population growth and low rates of agricultural productivity,** such as sub-Saharan Africa.

These regions are characterized by small farms, with little access to productive inputs. As production increases to meet the growing demand, concerns are rising about the environmental impact these low-productivity systems will have on the natural resource base, along with rising greenhouse gas emissions.

MEETING INDIA'S MILK DEMAND[14]



India has 10 times as many dairy-producing bovines as the U.S., but produces only 50 percent more milk. FAOSTAT (2014).

Over the next decade, India will account for 54 percent of the increase in global demand for fresh dairy products, requiring an additional 56 million tons of milk. India is already the largest dairy producer in the world, but dairy cattle and buffalo productivity is low.

In 2014, India had 50 million dairy cows and 40 million water buffalo, a total of 90 million animals producing 140 million tons of milk. Dairy cattle produce an average of 14,000 hectograms per animal and buffalo produce 19,000 hectograms per animal.

By contrast, the U.S. had just 9.2 million dairy cows and produced more than 93 million tons of milk, an average of 101,000 hectograms per animal.

Given the projected demand in India, improving the health and productivity of the current dairy cow and buffalo populations needs to be prioritized. Indian farmers and consumers are increasingly choosing buffalo over dairy cow milk. Consumers prefer the higher fat content of buffalo milk and it brings a higher return to farmers. Buffalo are more adaptable to the changing climate in India and they convert the low-quality indigenous grasses into milk more efficiently than cattle.

Improving genetics, feed and animal care practices can provide more milk using fewer animals. Increasing access to mechanization for small and medium-scale farmers would reduce reliance on cattle for draught power, allowing investments in milk production.

DOUBLING AGRICULTURAL PRODUCTIVITY IS THE RIGHT GOAL

The projected slowdown in demand for food and agriculture products over the next decade has prompted calls for a reduction in the agricultural output targets for 2050.[16]

Yet a large and growing body of sophisticated modeling by agricultural economists examining long-term scenarios for agriculture, food and the environment indicates that **it may be too soon to consider revising these goals downward.**

POLICIES TO HELP FARMERS BEAT CLIMATE CHANGE

Recent analysis of the climate impact on crop yields has produced sobering results. Each 1° Celsius increase in global mean temperature would result, on average, in a decrease in yields of maize by 7.4 percent, wheat by 6.0 percent, rice by 3.2 percent and soybeans by 3.1 percent.[17] The study's authors argue that **improved crop genetics and effective climate smart agriculture practices are the principal strategies for reducing climate impacts on crop yields.**

The development and widespread adoption of these technologies and practices will not happen without sustained policy leadership and innovation, particularly in low-income, food-deficit countries where productivity (TFP) rates are lowest. Avoiding the worst-case predictions of climate change on crop yields is still possible, but requires an immediate surge of investment in science-based innovation, since research pipelines require time to produce results that reach the field.

Public-sector investments in agricultural R&D support foundational research that the private sector further develops and brings to market, including drought and climate-resilient seeds, improved crop protection technologies, livestock breeds and health products and best practices in fertilizer use and animal care. A predictable, efficient regulatory environment stimulates private-sector R&D, enabling farmers to get the technologies they need, when they need them. Improved transportation infrastructure reduces the cost of agricultural inputs and increases access for small-scale farmers. New approaches to agricultural extension can more rapidly reach farmers with climate-smart agriculture innovations and practices, improving their ability to beat climate change.

The **Agricultural Model Intercomparison and Improvement Project (AgMIP)** is an international collaborative effort to improve agricultural economic models. AgMIP coordinates regional and global assessments of climate impacts and uses multiple scenarios for crop and livestock production across differing geographies to explore the effects of uncertainty, data selection and methodology on the models' results.

AgMIP's analysis of 10 leading global multi-sectoral projection models found that **world agricultural production of crops and livestock between 2005 and 2050 will need to rise by between 60 and 111 percent,** with demand growth particularly strong for ruminant products (cows, sheep) as well as for commodities used in the production of biofuels - sugar, coarse grains and oilseeds.[18] (The OECD/FAO prediction of a decrease in the rate of demand growth for food and agriculture products extends only to 2026, not to 2050.)

Most importantly, AgMIP points to the impact climate change will have on the ability of agriculture to meet future demand. **The 10 models suggest that climate change will generate higher prices for agricultural commodities in general and particularly for crops.** The impact of climate change must be considered to avoid a downward bias in projected supply estimates.

PRODUCTIVITY AND INNOVATION ARE THE KEYS TO THE SDGS

The United Nations Sustainable Development Goal 8 (SDG 8) lays out specific targets for the economic growth required to end poverty and hunger; in the least developed countries, this must reach at least 7 percent annual GDP growth. **The realization of UN SDG 8 will lead to higher demand for agricultural output in developing countries, where there is presently insufficient agriculture and food production.**

Doubling agricultural *productivity* from 2005 to 2050 is the right goal. It is aligned with the SDG 2 target of doubling agricultural productivity and incomes of small-scale farmers and food producers. It also considers the additional demand generated by achieving the SDG 8 target for economic growth. And it provides for the need to increase agricultural output while also conserving natural resources and reducing the climate impacts of agricultural production.

Increasing R&D investments is required to meet the SDGs. These investments enable farmers to produce food more sustainably while conserving natural resources. Without these innovations, farmers, particularly in food-deficit countries, will put more fragile land into production to increase output and will experience greater hunger and poverty.

Policies and Investments for Productive Sustainable Agriculture

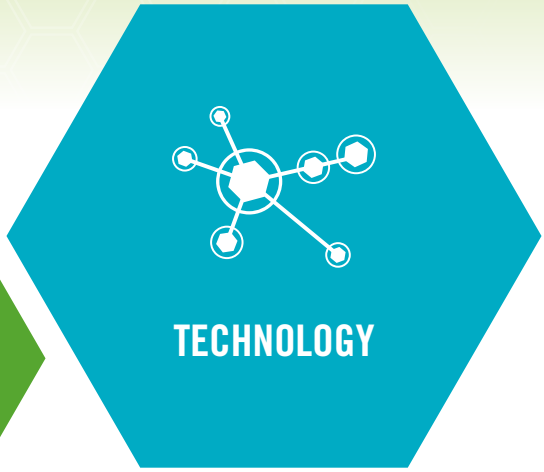
The right public policies and investments foster productive sustainable agriculture. The Global Harvest Initiative and its partners have identified five strategic policy goals that are essential to stimulating growth and resiliency in the agricultural value chain while helping farmers manage risks during challenging agricultural business cycles.

These policy goals are also aimed at reducing waste and loss in the agricultural value chain and helping mitigate climate change while creating opportunities for economic growth and innovation.

Invest in Public Agricultural Research, Development and Extension

The agriculture sector is heavily reliant on research and development (R&D) and extension programs to deliver innovation to farmers and others throughout the agricultural value chain. Agricultural R&D and extension programs are essential public goods and the principal drivers of Total Factor Productivity (TFP). Producers need access to proven techniques such as conservation agriculture and animal care practices to improve the sustainability and resilience of their operations.

Public R&D provides foundational results that the private sector can further develop to improve specific crops, livestock, machinery or food manufacturing industries. R&D and extension services help producers control costs, reduce loss and waste and become resilient to climate change while conserving natural resources. Public-private research partnerships leverage funds to tackle environmental, nutritional and economic challenges faced by producers and consumers.



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 and gene-editing 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. Innovative storage and cold-chain technologies ensure that more agricultural products reach markets rather than landfills.

Farmers use information technology to access vital information on market prices, weather, pests and soil health, while precision agriculture and data management tools help reduce costs and conserve scarce resources. Public policies that support the development, customization and dissemination of these technologies throughout the entire value chain are essential to nearly doubling global productivity in agriculture by 2050.

Enhance Private-Sector Involvement in Agriculture and Infrastructure Development

Policies that 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 open new markets and reduce transaction costs for producers and retailers. Reliable and affordable electricity and cold-chain systems as well as access to high-speed broadband make farmers more efficient and competitive, while reducing loss and waste in the value chain.

Collaborative efforts between government, industry and communities to develop an educated and entrepreneurially-minded workforce stimulate off-farm employment and reduce rural poverty.

Cultivate Partnerships for Sustainable Agriculture and Improved Nutrition

In striving to develop their agricultural economies and reduce malnutrition, governments often leverage partnerships with local and international private businesses, non-governmental organizations, foundations, multilateral institutions and development agencies.

Development assistance programs are moving beyond a "project" approach to embrace integrated, market-driven strategies 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 trade agreements efficiently move products to markets that need them, benefitting both producers and consumers.

Since many countries do not have the human or financial capacity to effectively manage complex regional and global trade opportunities, policies can start by building country capacity to facilitate local 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.

A World of Productive Sustainable Agriculture

Farmers, ranchers, fishers and forest managers are on the frontlines of the global effort to improve productivity and sustainability of food and agriculture systems. The challenges, choices and opportunities they face are unique to them and their operations, yet they share similar concerns and goals.

Consumers have a significant influence over the direction of the food and agriculture system. Through their pocketbooks they express their preferences and values, which helps shape the decisions producers make. For many consumers, low food prices and food safety are paramount concerns, while a growing number are interested in the environmental impact of their food choices.

The 2017 GAP Report® captures these perspectives through farmer and consumer stories from around the world.

These stories illustrate how people in our food and agriculture systems experience the global imperative to improve agricultural productivity and why it is crucial to meet the Sustainable Development Goals. **They provide insight into the complex and sometimes difficult choices that agricultural producers and consumers face, and how they try to balance the demands of today with the needs of tomorrow.**

Please note that while the individuals profiled here are composites of many people, these stories are not intended to represent the opinions of particular groups of farmers or consumers.

Krishna and Gita — India

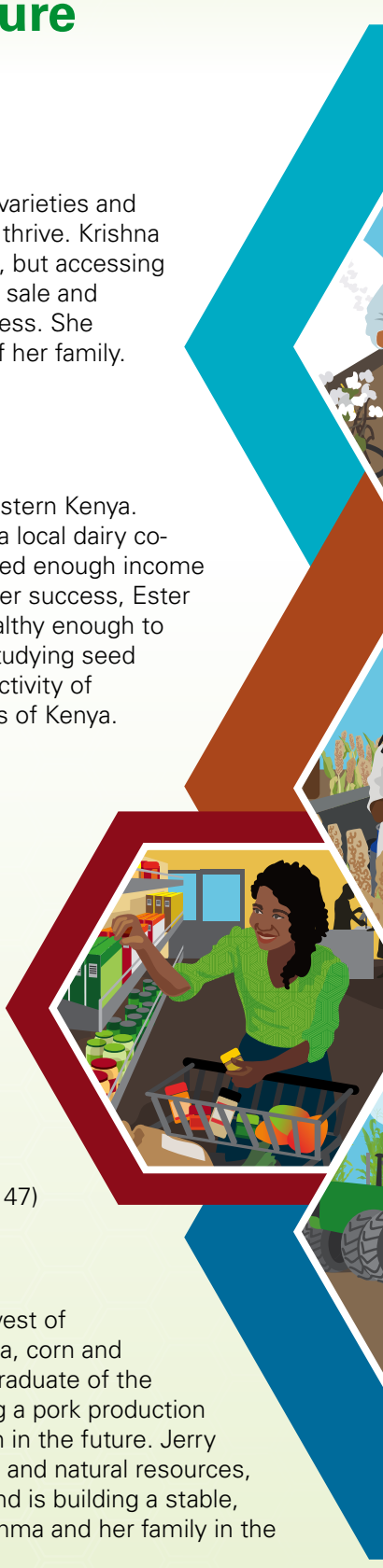
Krishna and Gita have used improved cotton varieties and drip irrigation to make their five-hectare farm thrive. Krishna would like to expand and mechanize his farm, but accessing financing is difficult. Gita grows tomatoes for sale and has ambitions to expand her vegetable business. She uses the income to improve the well-being of her family. (Pages 35–46)

Ester and Dalmani — Kenya

Ester is a dairy farmer in the Rift Valley of Western Kenya. She has 15 head of cattle and participates in a local dairy co-operative. Ester's dairy business has generated enough income for her daughter to attend university. For all her success, Ester is concerned about whether she will stay healthy enough to manage her farm. Her daughter Dalmani is studying seed science with the goal of improving the productivity of sorghum crops that are grown in the drylands of Kenya. (Pages 47–53)

Mercy — Kenya

Mercy just graduated from university and lives in Nairobi, where she grew up. She has an entry-level job at a local bank and shares an apartment with two friends. Now that she is responsible for her own food purchases, price is an important consideration, but she also likes to try new things. At the supermarket that recently opened in her neighborhood, she can buy foods from around the world, including packaged food from the U.S., seafood from Asia and fruit from India. (Page 47)



Jerry and Emma — United States

Jerry is a row crop farmer in the Upper Midwest of the U.S., and for 35 years he has grown alfalfa, corn and soybeans. His daughter, Emma, is a recent graduate of the state agricultural university. She is developing a pork production business while preparing to manage the farm in the future. Jerry practices restorative farming to conserve soil and natural resources, is diversifying his operations to reduce risk and is building a stable, sustainable business that he can leave for Emma and her family in the coming years. (Pages 20–34)

Ava and Ben — United States

Ava and Ben live in an urban area in the U.S. Midwest. Like many in their circle of friends, they have concerns about the impact of agriculture and food production. They want to learn more about the relationship between food production and climate change, and they want to be sure wildlife are protected and natural resources like water, soil and forests are used sustainably. They also want a closer connection with farmers and the food they buy, and try to eat fresh, healthy food while considering price as well. (Page 20)

Minh and Trang — Vietnam

Minh and Trang grow rice on two hectares of land in the Mekong Delta in Vietnam. Trang has decided to focus on improving rice productivity and quality, as well as more intensively farmed shrimp. Her husband Minh would like to shift some of their land to corn production to earn more money, but he needs agronomic advice. The area of the Mekong Delta where they live is becoming increasingly saline, which is threatening the economic and environmental viability of their farm. (Pages 54–59)

Shen Nianzi — China

Shen Nianzi lives with her husband and son in a fast-growing city in southeast China. While her husband prefers to eat chicken and pork, she has decided to increase her family's consumption of vegetables, which she purchases at a new modern retail store near her home. She is very concerned about rice and other food crops that may have been grown in contaminated farm soil, so she is willing to pay more for trusted brands that are safe and high-quality. (Page 47)

Doña Rosa and Don Julio — Colombia

Doña Rosa and Don Julio live in a mountainous area of rural Colombia where they raise 90 cattle on their ranch for both meat and milk. The local climate and weather patterns are shifting, making their livestock and farm vulnerable to drought and heat. They are working closely with the government, technical assistance organizations and conservation agencies to improve the resilience of their farm by establishing a silvopastoral production system. (Pages 60–66)

Ava and Ben live in an urban area in the Midwest of the United States. Like many in their circle of friends, they have concerns about the impact of agriculture and food production. They want to learn more about the relationship between food production and climate change. They also want to be sure livestock are cared for and natural resources like water, soil and forests are used sustainably.

Even though they are not directly involved in farming, they are interested in having a closer connection with farmers and the food they buy. They enjoy visiting their nearby farmer's market and try to eat fresh, healthy food while considering price as well.

Ava and Ben are indicative of the growing and diverse consumer demand that is driving dramatic changes in the food and agriculture system. Many consumers buy in bulk and are focused on getting the best price for safe, nutritious food. Other consumers want fresh and prepared foods in single-portion containers, and many are reading labels and asking about ingredients and production methods. A growing number of consumers are concerned about the environmental and social impact of agriculture and food production, and want to understand more about farming methods and the food they eat.

Forging new relationships and conversations between consumers like Ava and Ben and farmers like **Jerry and Emma** helps close the "trust gap" that exists in many countries today. Farmers, agribusinesses, consumers and the government must seize opportunities to discuss how productive farming systems contribute to food security while realizing the sustainable agricultural imperative.

The Next Generation of American Agriculture

Jerry's farm in the U.S. Upper Midwest consists of 1,200 acres planted with alfalfa, corn and soybeans, along with cover crops. He owns 800 of these acres and rents 400 acres as part of a cost-effective strategy to expand his production.

During the 1980s downturn in the farm economy, Jerry witnessed the hardships experienced by his neighbors. As a result, he has focused on managing risks by diversifying the crops he grows, improving the quality of his crops and livestock and by adopting science-based innovations that help him manage costs while increasing his yields.

Jerry sells most of his crops to grain handlers, but he uses some of the crops grown on the farm to provide feed for his expanding pork operation, managed by his daughter, Emma. Today his focus is on practicing restorative farming to conserve soil and natural resources, diversifying his operations to reduce risk, and building a stable, sustainable business that he can leave for Emma and her family in the coming years.

BETTER BREEDING FOR A BETTER FUTURE

For several thousand years, agriculturalists have improved the quality and performance of crops and livestock through trial and error, saving seeds from plants or breeding animals from those that exhibited the desired traits.

Between the 1920s and 1950s, breeders significantly improved crop yields by creating hybrid (cross-pollinated) crops. When the structure of DNA was discovered in 1953, plant breeders were able to more precisely change a plant through modern biotechnology by either introducing a trait from a wild relative of that crop or from another species, or by altering the plant gene itself.

Today, the tools used by agricultural breeders have evolved through science-based innovations. With an ability to understand the genetic sequence of plants and to link a particular gene with a specific plant characteristic, breeders can quickly and efficiently improve plants while avoiding the transfer of unwanted genes.

In the past decade, new gene-editing techniques such as CRISPR-Cas[1] have become available, unlocking potential benefits for farmers, consumers and the environment. Breeders can now edit genes by turning on or off various genetic functions that increase crop yields during drought, protect the plant or crop against viruses and pests (reducing the amount of pesticide needed), improve the nutritional quality and content of crops or help vegetables maintain longer shelf life. Gene-editing technologies such as CRISPR-Cas rely on natural processes that happen in the genome, but channels and targets those changes more precisely.

Seed companies are exploring how this technology allows breeders to develop better hybrids by quickly finding and leveraging the inherent diversity existing in crops.

DuPont Pioneer has developed a higher yield gene-edited type of corn (waxy corn hybrids) useful for many industrial processes. This corn will be available for farmers to use after field trials and regulatory reviews are completed. To fight a devastating corn disease affecting small-scale farmers in Africa (maize lethal necrosis), DuPont and the **International Maize and Wheat Improvement Center (CIMMYT)** have formed a public-private research partnership using CRISPR-Cas technology.

Plant breeding innovations like CRISPR-Cas will only be achieved through active engagement and collaboration with farmers, academia, governments, NGOs and public research institutes, both in the United States and around the world.

CROP PRODUCTIVITY BUILDS THE FOUNDATION FOR SUCCESS

The high productivity of Jerry's alfalfa, corn and soybean crops derives from decades of collaborative research on the part of the federal and state governments, agribusiness companies, entrepreneurs, land-grant colleges and universities and extension agents — and most importantly from farmers like Jerry who take risks and adopt innovative, science-based and information technologies on their farms such as new seed varieties and precision agriculture.

Over the past 30 years, Jerry has worked closely with extension agents from the state university and with private-sector companies, as well as crop and farm advisors and agricultural retailers. They have helped him gradually boost the yields and quality of his products and adopt proven practices in conservation and sustainability.

Innovations in crop genetics, crop nutrients and crop protection products, along with precision agriculture technology on machinery, have enabled Jerry to produce more high-value crops per acre while reducing his business costs and environmental footprint. Widespread

(continues on page 23)

CROP PRODUCTIVITY BENEFITS THE U.S. AND THE WORLD

The United States is the world's largest corn producer and currently exports between 10 and 20 percent of its annual production.[2] Corn is the most widely produced feed grain in the U.S. and is also processed into a range of food and industrial products.

Between 1980 and 2015, corn yields in the U.S. improved by 61 percent. When measured per bushel produced, corn productivity also improved: land and energy used in corn production each declined 41 percent, irrigation water declined 46 percent, greenhouse gas emissions (GHG) declined 31 percent, and soil erosion declined (tons of loss per acre) by 58 percent.[3]

Processed soybeans are the world's largest source of animal protein feed and the second largest source of vegetable oil. The United States is the world's leading soybean producer and the second-leading exporter.[4]

Between 1980 and 2015, soybean yields in the U.S. improved by 29 percent. When measured per bushel produced, soybean productivity also improved: land used in soybean production declined 40 percent, irrigation water declined 32 percent, energy use declined 35 percent, greenhouse gas emissions (GHG) declined 38 percent and soil erosion declined (tons of loss per acre) by 47 percent.[5]

Figure 6: Index of Resource Use to Produce Corn, U.S., 1980–2015

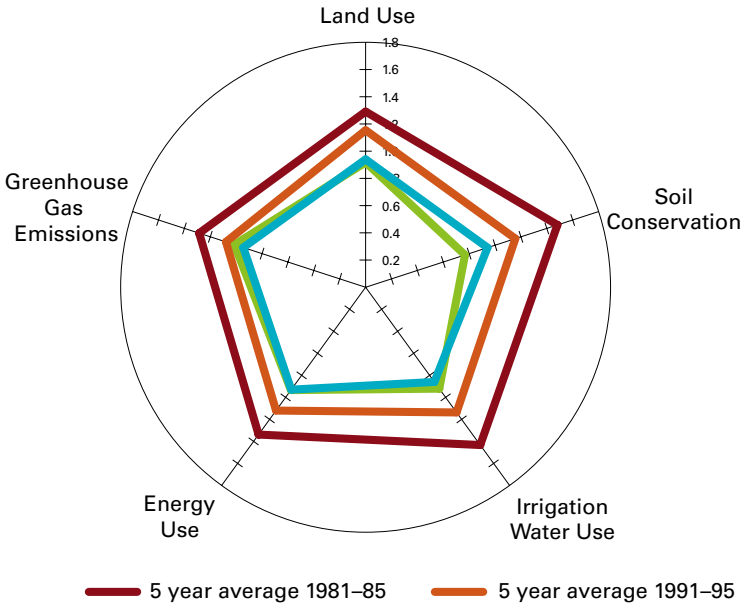
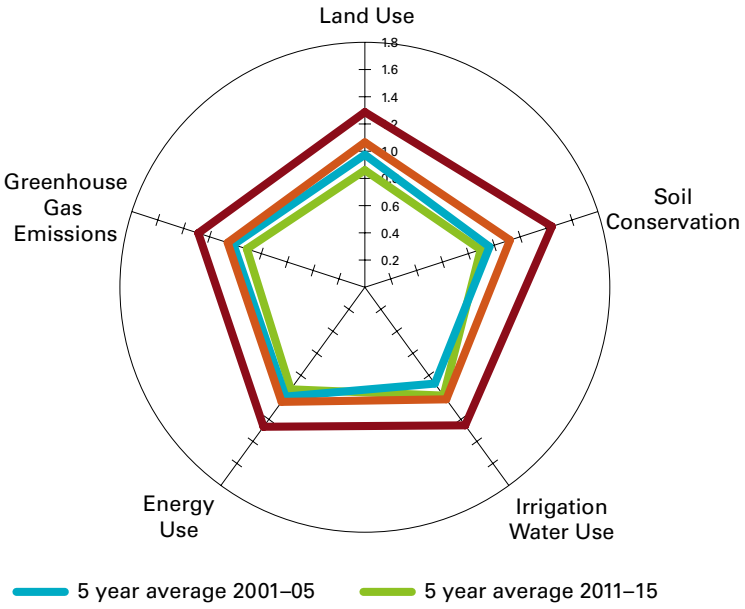


Figure 7: Index of Resource Use to Produce Soybeans, U.S., 1980–2015



Source: Field to Market, 2016

use of these innovations by U.S. farmers has resulted in lower prices of food, fiber and biofuels for consumers.

Since he gradually began taking over the family farm operation from his parents in the 1970s, Jerry has increased the size of his farm and diversified the crops he grows to manage risks when weather or crop prices pose a challenge.

In addition to corn and soybeans, Jerry grows alfalfa and oats as part of a crop rotation strategy. Alfalfa provides high-protein forage for livestock and when planted in a field rotation before corn, it fixes substantial amounts of nitrogen in the soil that can be utilized by the corn plants.

During the 1980s, Jerry was able to increase his farm size by purchasing land when prices were lower. Due to higher land prices today, he accesses additional farm acreage through a contract rental arrangement with a real estate investment company, enabling him to free up capital for purchases such as precision agriculture equipment or to invest in his daughter's pork production enterprise.

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RENTING LAND, REDUCING RISK

As the population of the United States increases, urban development and suburban expansion into prime lands used for agriculture takes place. Conversion of farmland and forests for human settlements reduces land available for food and timber production, and releases carbon sequestered in soils.

> By 2030, the world will lose 1.8% to 2.4% of highly productive croplands due to urban expansion.[6]

More than 24 million acres of U.S. agricultural land were developed for other uses between 1982 and 2017; it is unlikely that this land will be restored to farming or ranching operations.

U.S. farmland and ranchland is some of the most productive and expensive agricultural land in the world. Many farmers today are unable to expand their operations and gain access to additional high quality farmland, either due to competition from urban development or, as in the case of newly emerging farmers, a lack of sufficient capital and access to credit to purchase farmland.

> 40+ acres of U.S. farm and ranch land are lost every hour to urban sprawl or development.[7]

Renting land from other landowners or from real estate companies that specialize in supporting farming operations are options for farmers who wish to expand their operations. Contract farming through rental of land allows farmers to do what they do best: grow crops or raise livestock without incurring debt and risk associated with purchasing land.

Institutional land investors such as **Farmland Partners Inc.** build long-term leasing relationships with farmers and invest in the capital improvements that increase the productivity of farms. As of July 2017, Farmland Partners owns or has under contract more than 154,000 acres located across 17 states, farmed by more than 124 tenants growing more than 30 major commercial crops.

Other opportunities to gain access to land are provided by the **USDA Transition Incentives Program (TIP)**, which encourages current landowners with expiring **Conservation Reserve Program (CRP)** contracts to sell or lease their land to beginning or socially disadvantaged farmers, or to military veterans. TIP provides retiring land owners with an incentive to return land to production in a way that preserves established conservation practices. It also provides beginning and socially disadvantaged farmers and ranchers opportunities to affordably purchase or rent land.

States such as **Minnesota** are also tackling the challenge by offering a state income tax credit to current landowners when they sell or rent land to a beginning farmer. Organizations like the **National Young Farmers Coalition** are advocating for more state and federal solutions. Young farmers often mention access to land as a top challenge, and state and federal legislation that incentivizes the transition of land to beginning farmers helps them seize the opportunity to grow food and help rural communities thrive.

A rye cover crop protects the soil between soybean rows.

FARMERS BUILD SOIL HEALTH TOGETHER

Farmers understand that healthy soils are the starting point for farm productivity and sustainability. When they work together to conduct research and experiment with best practices, farmers become powerful change agents.

Research from U.S. land-grant universities has shown that managing a crop for optimal nitrogen use and productivity also increases soil organic carbon, which in turn boosts crop productivity while reducing nitrogen loss.[8] Nitrogen and phosphorous use has improved corn yield in the U.S.[9] and greenhouse gas emissions are minimized under these highly productive systems, demonstrating the link between productivity and sustainability.[10]

The **Soil Health Partnership (SHP)** is a farmer-led collaboration initiated by the **National Corn Growers Association** that brings together farmer leaders committed to improving the sustainability of their farms with a strong focus on soil health and productivity. As of 2017, SHP has a network of more than 100 demonstration farms to showcase best practices.

Together these farmers are testing and measuring farm practices like growing cover crops, implementing conservation tillage (such as no-till or strip-till practices) and managing nitrogen and phosphorous fertilizers to maximize their benefit while reducing negative impacts on water quality.

Research has shown that no-till cropping systems tend to improve soil health over the long run, but the transition from tilling to a no-till system requires a sustained commitment from farmers and education and support from others, as declines in yield may happen in the first years of the transition period. By adding cover crops, soil health can build up more quickly during the transition to a no-till system, thereby restoring higher yields sooner.

While some cover crops are harvested for profit, the primary use of cover crops is to improve soil for the main crops of corn, wheat, soybeans or other row crops that are planted after the cover crops mature. Cover crops reduce soil erosion from wind and rain. Below the surface, their root systems support soil structure and retain nutrients, particularly nitrogen, phosphorous and potassium.

Cover crops such as ryegrass, winter rye, clover, hairy vetch and alfalfa are planted alongside row crops (corn, soybeans, wheat) at optimum times during the growing season to keep living plants in the fields as long as possible, anchoring the soil and preventing erosion. Legumes and grasses are extensively used, as well as brassicas (such as rape, mustard and forage radish).

Cover crop roots also reduce soil compaction and improve the ability of fields to conserve water after rainfall, thereby reducing the amount of irrigation water required. The organic matter left behind by cover crops contributes to soil organic matter, which improves soil fertility and the yields of other crops grown in the field.

The **USDA Natural Resource Conservation Service** and private-sector companies such as **Monsanto** participate in the SHP by providing funding and guidance, and conservation organizations including **The Nature Conservancy** bring technical assistance. The **Midwest Row Crop Collaborative** has contributed additional funding so that over the course of 10 years, the SHP will provide a set of specific, data-driven recommendations that farmers across nine Midwestern states can use to improve the productivity and sustainability of their farms.

Getting hands in the soil is the best way to foster discussion at an SHP field day in Lynnville, Iowa. Photo Credit: Soil Health Partnership

BECOMING A GOOD STEWARD OF SOIL AND WATER

Jerry wishes to preserve and improve his most important natural asset — his farm soil — and wants to do his part to ensure there is clean water for drinking and recreation. Thus, he has implemented innovative soil management practices based on local climate and soil conditions, reducing the environmental impact of his farming operations.

In the 1980s, Jerry experimented with organic farming, but found that for his farm, tilling the soil to plant seeds and manage weeds resulted in higher erosion and losses of sediment and nutrients into nearby streams, as well as unnecessary wear and tear on his farm machinery.

Jerry receives soil management training from his state agricultural extension office. The training helped him make the transition from tilling his soil before planting crops to a no-till system of weed and soil management that builds the organic matter of his soil. Using biotech corn and soybeans that are genetically modified to be herbicide-tolerant is part of a no-till system, and it enables him to reduce the amount of herbicide he applies to his fields.

Jerry shares his knowledge and experience with new farmers at **Soil Health Partnership (SHP)** field days and with agriculture and environmental science students from nearby land-grant colleges and universities who visit his farm to conduct research and observe his practices.

To advance stewardship of land and water, Jerry consults with crop and farm advisors who help him assess variations in slope and soil types to understand field hydrology. Based on their analysis, he invested in field tiling (underground pipes that funnel excessive water after rains) for certain parts of the field where rainfall could cause problems with flooding.

He also works with extension agents, a crop advisor and a machinery advisor from a farm machinery dealership to establish a precision farming plan for field preparation, planting and seeding, crop care and harvesting.

Following several years of high prices for crops, Jerry invested his profits into the purchase of a new tractor equipped with auto guidance that helps him accurately pass through fields, avoiding overlap and wasted fuel. He also invested in field

SHP Eastern Iowa Field Manager Elyssa McFarland examines a soil sample at an Eagle Grove, Iowa field day. Photo Credit: Soil Health Partnership

SMART FARMING WITH PRECISION AGRICULTURE

Precision agriculture is the use of data and technology to increase the productivity and profitability of agricultural operations, including crops, livestock, aquaculture, dairy, forests and orchards.

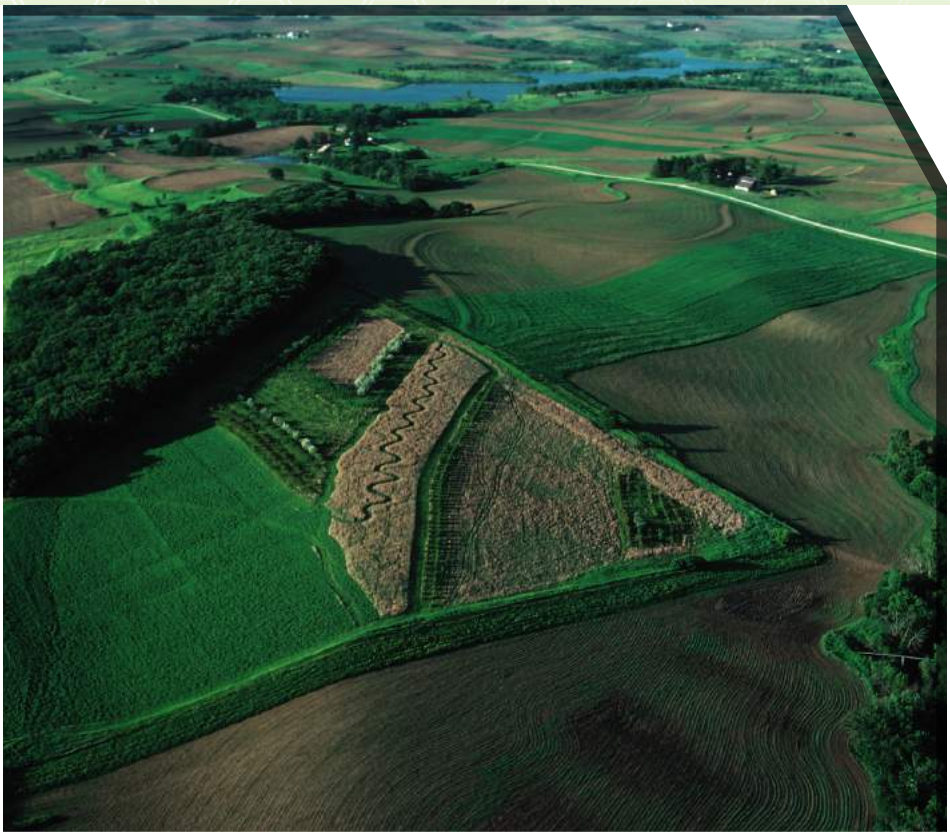
Farmers use tractors, combines and sprayers with global positioning system (GPS) devices and precision guidance satellite receivers enable them to navigate for sub-inch accuracy in their crop fields. Using integrated software that contains data about their operations, farmers can precisely apply nutrients, control weeds and pests and add water where it is needed for maximum yield.

For livestock operations, sensors on the animals can alert farmers to the presence of a disease before it spreads throughout an entire herd. Farmers are now investing in automated and computer controlled barns that provide consistent temperatures and readily available feed and water.

In forest operations, remote sensing images can measure tree height and canopy information, as well as tree diameter and biomass, as part of a carbon sequestration strategy. Estimating timber volume allows forest managers to make better decisions about where and when to harvest trees.

39% of the U.S. rural population (23 million people) lack access to broadband internet service, compared with 4% of U.S. urban residents.[11]

Precision agriculture systems continue to spread as the technology improves and is more widely adopted by farmers of all scales around the world, but adoption is limited in many rural areas due to a lack of broadband service. To take advantage of precision systems, farmers need access to farm-wide, high-speed and high-quality fixed broadband and mobile cellular coverage.

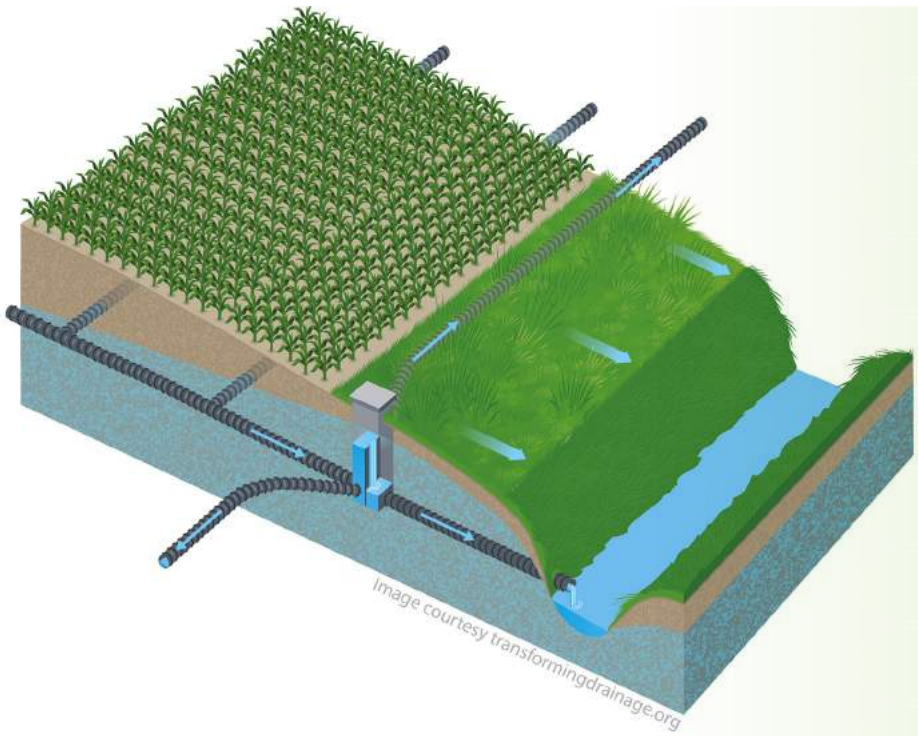


Prairie grass and pollinator and woodland habitat on farms on less productive land. Photo credit: Tim McCabe, USDA NRCS

sensors that collect data about soil moisture levels and nutrient profiles, enabling him to use precise fertilizer applications only where the soil requires it.

Using a software system that integrates field data and climate information, Jerry generates maps that depict the considerable soil variation across his fields. He makes highly accurate and timely decisions about when and where to plant, uses precision prescriptions to apply fertilizer or crop protection products in the right amount and at the right time to avoid product losses after heavy rains, and knows when is the best time to harvest.

More recently, Jerry has increased his income by focusing on producing and selling high-quality livestock feeds. He uses special sensors and a software program developed by **John Deere** (Constituent Sensing, part of HarvestLab) to measure the



Saturated buffers store water from the field through subsurface tile tubes and divert it into shallow lateral tiles where it is slowly filtered through the soil and plant roots before it enters a stream. Saturated buffers are one form of edge of field practice used to protect waterways from fertilizer and sediment runoff.

Image courtesy of The Transforming Drainage Project. The Project addresses the need to provide more secure water for crops throughout the growing season while maintaining adequate drainage during wet periods and limiting nutrient losses from drained agricultural landscapes. To learn more, visit https://transformingdrainage.org.

nutrient quality of his corn and alfalfa. Constituent Sensing informs Jerry about the protein, starch and fiber content of his crops, allowing him to make adjustments that result in greater quality and value of his final feed product and thereby reduce spoilage and losses.

Jerry now maintains a growing database of information about his farm, so he can manage and track annual progress towards maximizing the productivity of each part of his land. He has learned which areas of his fields regularly do not produce higher yields and are vulnerable to erosion. He has placed this less productive land into conservation through the **USDA Conservation Reserve Program (CRP)**, establishing a pollinator habitat for bees and wildlife.

A challenge Jerry faces is a lack of access to broadband for approximately 200 acres of his farmland. As a result, he is unable to integrate this land into his farm management system, making it more difficult to track and plan for productivity and environmental improvements.

In addition to practicing no-till farming, planting cover crops and using precision agriculture, Jerry is advancing water quality by adopting nutrient management and edge-of-field practices. With the advice of his agricultural retailer, he practices **4R Nutrient Stewardship** (choosing the right nutrient source to apply at the right rate in the right place at the right time) and has also installed a **saturated buffer** at the edge of his field that runs alongside a stream.

Agricultural producers who reside in targeted watersheds can apply for federal assistance through **USDA's Regional Conservation Partnership Program (RCPP)** to install buffers and other water quality innovations like improved drainage water management and constructed wetlands. The RCPP leverages public and private partners for funding and support as farmers make water quality improvements on their farms.

Jerry continues to cultivate healthy soils that sequester carbon while keeping the soil and fertilizer on his farm and away from waterways, boosting the productivity of his crops. He has received recognition from the governor of his state for his exemplary efforts to improve water quality, conservation for wildlife habitat and soil health.

While Jerry has built a strong farm business model during the past 30 years, he continues to rely on the **crop insurance safety net** to help him during exceptionally bad years of drought or weather disasters that can wipe out much of a crop during a growing season.

The **2014 Farm Bill** increased funding for crop insurance subsidies for farmers like Jerry who purchase corn and soybean crop insurance. He would like to see options for expanding insurance coverage to swine production and alfalfa, given that he and his daughter produce these on their farm. With shifting weather patterns and climate change, Jerry wants to be sure that multiple years of drought or more catastrophic events do not destroy the crop and pork production business for Emma.

(continues on page 29)

4R PARTNERS PROMOTE WATER QUALITY

Water availability and quality are critical for human health, recreation and agricultural production. Water quality and agricultural production methods are closely interlinked, and there is an urgent need for farmers and agricultural retailers to adopt best practices that protect water quality and to become advocates to scale up these practices more widely.

To improve crop yields and soil health, farmers apply nitrogen and phosphorus in the form of commercial fertilizer or manure. When these nutrients are not properly applied, or when storms and heavy rainfall occur, nutrients flow off the fields through streams, eventually reaching large bodies of water where they enrich harmful algal blooms or "dead zones" that lack sufficient oxygen to support aquatic life. Such areas in Lake Erie, the Gulf of Mexico and the Chesapeake Bay pose a serious challenge today.

To meet these nutrient management challenges, farmers are increasingly using **4R Nutrient Stewardship** practices: choosing the right nutrient source to apply at the right rate in the right place at the right time. Farmers work closely with crop consultants, agronomists and agricultural retailers to develop annual plans for their fields, including how to ensure that crops maximize the uptake of nutrients and how to prevent sediment and nutrient runoff into waterways.

The Western Lake Erie Basin (WLEB) encompasses parts of Ohio, Michigan and Indiana and spans 8.3 million acres. Several major rivers drain into Lake Erie and most of the land in the basin is now used for agriculture, industry and urban development. Only five percent of the basin's wetlands remain, along with a small forested area.

Since 2012, **The Mosaic Company** and **The Mosaic Company Foundation** have played an active role in the development, launch and funding of the **4R Nutrient Stewardship Certification Program** in the WLEB. The program is governed and administered through the **Nutrient Stewardship Council** and the **Ohio Agribusiness Association**, and includes more than 20 agriculture and environmental organizations.

Today's agricultural retailers reach more farmers and acreage than ever before, and they provide high quality agronomic services and advice as part of their business model. Recognizing this opportunity, agricultural, environmental and community groups formed the **Nutrient Stewardship Council** to create the **4R Certification Program** for retailers. The certification process includes 44 standards across three categories: 1) training and education in 4R practices; 2) monitoring 4R implementation; and 3) nutrient and application recommendations. Annual audits conducted by third parties help the retailers maintain and verify their practices.

As of July 2017, 44 retailers across the WLEB and the entire state of Ohio have achieved certification in the 4R Nutrient Stewardship Program. Together they are reaching 5,900 farmers and 2.76 million acres with science-based, proven practices that keep fertilizer in the crops and soils rather than in Lake Erie.

> After just 2 years, the 4R Program impacted 35% of the farmland in the WLEB, with the potential to soon reach nearly all farmland in the watershed.[12]

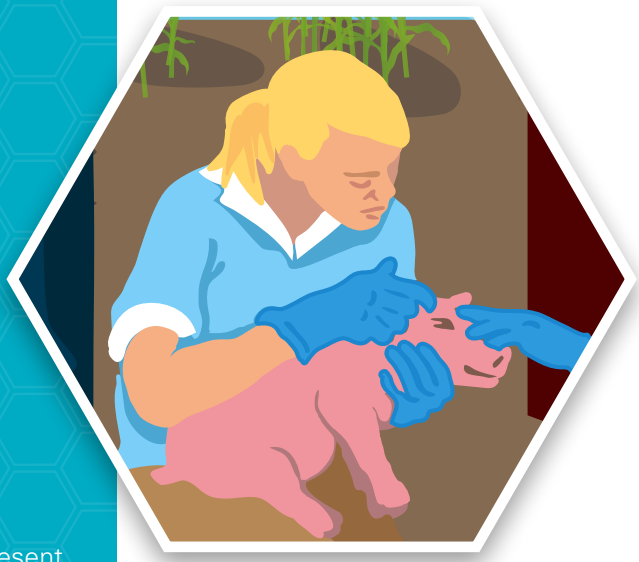
Ongoing evaluation of the program's progress is made possible by a five-year grant from the **4R Research Fund**, sponsored by companies in the fertilizer industry including The Mosaic Company. Efforts continue to expand the program and reach more farmers each year.

4R Advocates Expand Their Reach

Since 2012, the **Fertilizer Institute** has recognized 30 farmers and 30 agricultural retailers as **4R Advocates**. These 60 professionals represent 144,425 acres of cropland across 17 states. They share the benefits of proper nutrient stewardship with other growers and partner with conservation and environmental groups to ensure a wider understanding of the importance of soil and plant health.

Among the practices they advocate for are the following: incorporate fertilizer into the ground rather than broadcasting it; delay application for fields that are prone to flooding; avoid applications before heavy rains or when soils are frozen; and avoid applying fertilizers near ditches, streams or waterways.

(l to r) Crop advisor, Scott Bergsieker, with grower Lynn Fahrmeier in Missouri



DIVERSIFYING FOR RESILIENT GROWTH

Given the challenges that many farmers in the U.S. have faced with boom and bust agricultural economies, and listening to her father's advice about the importance of being ready for an uncertain future, **Emma** has decided to continue the path of diversification on her father's farm.

Emma studied livestock and farm management at her nearby land-grant university and is now focused on building the family pork production capacity — but with an eye to specialization and consumer engagement.

Noting the growing consumption of various specialty pork dishes by her friends and learning about the growth in pork demand from Mexico and throughout many countries in Asia, she has decided to develop and expand the farm's production capacity by providing high quality pork for domestic and export markets.

Emma benefits from decades of public research and development that has translated today into high pork productivity in the United States.

Today it only takes 5 breeding hogs to produce the same amount of pork from 8 hogs in 1959, or 38% fewer breeding animals.[13]

Her business would benefit from new trade agreements with countries in Asia that enable her to compete for those growing markets against producers from the European Union (EU).

Caring for pigs, especially during farrowing (when pregnant sows give birth) and during the critical period for piglets after birth, requires workers who can be available around the clock. Along with many ranchers, dairy farmers and horticulture producers, Emma faces a critical shortage of labor to ensure year-round productive operations and well-cared for animals.

In the U.S., farming, fishing and forestry account for 20% of all immigrant workers.[14]

Emma and other farmers are waiting for policy solutions such as immigration reform to help meet her need for year-round labor. In the meantime, with her father's support Emma acquired a loan to invest in a new state-of-the-art barn, allowing her to put in place some of the highest pork industry standards for animal care, environmental management and to maximize productivity.

Emma is an independent contract grower in a multi-year agreement with **Smithfield Foods**. While Smithfield assumes the market risks and owns the hogs, Emma raises and cares for them. Under the agreement, she is protected from market fluctuations and receives a predictable income stream.

Emma also agrees to abide by **Smithfield's Animal Care Management System**, with verification of compliance. The system includes requirements for: shelter that meets the animals' needs; access to adequate water and high-quality nutritional feed; humane treatment of animals that complies with all applicable laws and regulations; identification and appropriate treatment of animals in need of healthcare; and use of humane methods to euthanize sick or injured animals not responding to care and treatment.

Smithfield encourages contract growers to install group housing systems for pregnant sows. Once confirmed pregnant, the sows are housed in groups until they are ready to give birth.

SUSTAINABLE SHARED VALUES

Emma wants consumers to understand how she manages her farm and how she puts into practice her values of sustainable production and animal well-being.

She creates short videos for her website and hosts a live weekly web chat from her farm. She also interacts with consumers at farmer's markets and explains how she cares for her pigs and implements sustainable production methods.

In addition to demonstrating many aspects of pork production and animal care with her social media feed, Emma also discusses how the carbon "hoofprint" of pork production is being lowered on her farm.

PRODUCTIVITY FEEDS RISING GLOBAL PORK DEMAND

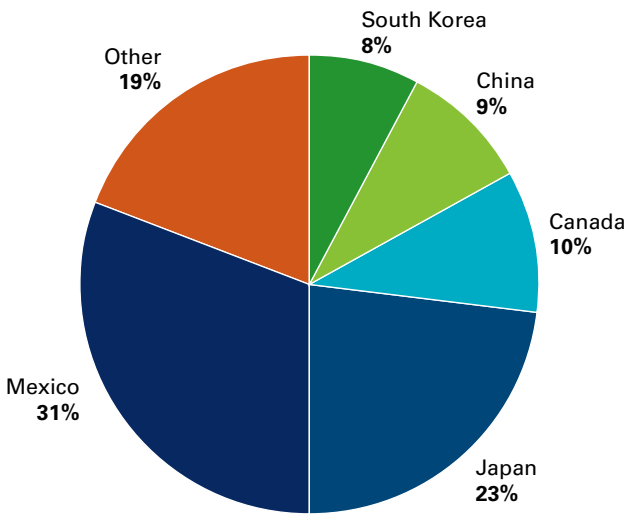
As recently as 1989, the U.S. was a net importer of pork; today it is a net pork product exporter, reaching more than 100 countries. The U.S. exported nearly 26 percent of its domestic pork production in 2016, with most of the demand coming from Mexico, Japan, Canada, China and South Korea.[15] Consumers in these markets trust the safety and quality of U.S. pork products and demand continues to grow.

The **Trans-Pacific Partnership (TPP)** trade agreement would have reduced tariffs on U.S. exports of pork to Asia and Pacific markets. Without the TPP agreement, U.S. pork producers will lose $387 million in sales per year, primarily due to tariff reductions that would have taken place in the Japanese market.[16] Competitors such as the EU are filling the demand gap by negotiating new agreements with many of these countries.

Producers in the U.S. also face uncertainty over future exports to Canada and Mexico as the **North American Free Trade Agreement (NAFTA)** is renegotiated. In 2016, the U.S. shipped $2 billion in pork products to Mexico and Canada, and if tariff levels increase due to a renegotiated treaty, pork producers will lose critical revenue.

Ensuring that trade is open, fair and based on common scientific standards with low tariffs will enable U.S. farmers to sustainably meet the growing demand for pork and other livestock products among the expanding consumer classes in Asia and Mexico.

Figure 8: Country Shares of U.S. Pork Exports, 2016



Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service, Production, Supply and Distribution (PS&D) database.

Smithfield Foods is on track to fulfill its commitment to transition all pregnant sows on company-owned farms to group housing systems by the end of 2017. Photo credit: Smithfield Foods

SMART BARNS FOR HEALTHY PIGS

Many pork farmers are now investing in automated computer-controlled barns for their animals, providing consistent temperatures and readily available feed and water.

Waste falls through slatted floors where it is moved to storage tanks or anaerobic lagoons until it is ready to be land applied as fertilizer, in accordance with environmental permits. Containment of manure in this manner reduces loss to the environment and provides a valuable source of fertilizer or energy. Use of precision data in the smart barns allows farmers to increase productivity by reducing energy use and saving labor while protecting pigs from predators and disease. Feed for the pigs is formulated to maximize nutrition and optimize growth and reduce levels of nitrogen in pork manure, thereby reducing environmental impact and cost for the farmer.

Pigs are housed with temperature control and monitors for early detection of disease or lameness so problems can be addressed before impacting the entire herd. Fans, misters and heaters are part of the climate control systems in these smart barns. Some of the new technologies include personal ear tags that allow workers to check them for health and expected farrowing date.

Many pork production companies are shifting to new systems of housing for pigs, especially for pregnant sows. Companies such as **Smithfield** require their U.S. company-owned farms to convert their housing from individual gestation stalls to group housing systems for pregnant sows by the end of 2017. In addition, Smithfield recommends that its contract sow growers transition to group housing by 2022. The company is providing guidance and expertise to help contract growers reach this target.

Each group housing design has unique advantages and disadvantages for the well-being of the sow. For example, it may allow free roaming of the pigs, trickle watering and electronic feeding stations, and deep bedded areas. Improving both the animal husbandry skills of the caretaker and science-based housing will support the productivity and comfort of the animals.

Pork production in the U.S. today has a small carbon footprint, with just 1/3rd of 1% of total U.S. greenhouse gas (GHG) emissions.[17]

Emma works to produce healthier herds that make better use of all resources, such as feed and water, while reducing waste and loss. Her approach to comprehensive improvements in herd management includes data collection to understand variations in her herd, provision of nutritious and sustainable feed and controlling disease while making sure all pigs reach an optimum weight for market.

Improving the efficiency and nutrition of animal feed brings environmental benefits and cost reductions to pig farmers. The highly productive alfalfa, biotech corn and soybean crops produced on Jerry and Emma's farm provides an excellent feed base for livestock. Emma works with veterinarians and her father to formulate highly nutritious feeds that include enzymes to enhance nutrient uptake, and she uses health products that prevent disease, especially in newly-weaned piglets.

Between 1959–2009, pork feed efficiency improved by 33% and crop yield increases led to a 78% decrease in land required per 1,000 pounds of pork produced.[18]

KEEPING PIGS HEALTHY

Pork producers focus on keeping their pigs healthy during their entire life-cycle. Receiving good training in animal husbandry, regularly monitoring their herds and scheduling visits from veterinarians are all practices that ensure pigs stay healthy and that disease can be detected early.

A particularly vulnerable time for piglets happens during the nursery phase after weaning. Pathogenic *E. coli* is prevalent in livestock herds and causes post-weaning diarrhea lasting up to 14 weeks of age, threatening the health and lives of piglets. **Elanco Animal Health Company** has conducted extensive research and developed an animal-use-only antibiotic (Kavault™) that veterinarians can prescribe as a feed additive that is proven to reduce the incidence and overall severity of diarrhea from *E. coli* in groups of weaned pigs.

Another disease of great concern to the entire livestock sector is the deadly **foot-and-mouth disease (FMD)**, a highly infectious virus that affects cattle, pigs and sheep. While no outbreaks have occurred recently in the United States, it is endemic in many parts of the world. An outbreak in the U.S. would result in the closure of export markets, resulting in a wide economic ripple effect across the entire agricultural industry. Surplus pork, beef and sheep in the domestic market would reduce demand also for corn and soybean feeds, with estimated losses of $128 billion for livestock, $69 billion for corn and soybeans, and 1.5 million jobs lost during the recovery decade.[19]

To mitigate an outbreak of FMD and maintain food security in the U.S., an adequate vaccine bank must be maintained. Sufficient supply of FMD vaccine must be available for early, robust action to vaccinate herds of animals near an outbreak to prevent the national spread of the disease.

Policy Priorities for Improving Productivity and Sustainability in United States

Farmers in the United States face new challenges from changing consumer preferences, low commodity prices, volatile weather conditions and uncertain global trade patterns.

The upcoming reauthorization of the U.S. Farm Bill and the potential for new investments in research and infrastructures for transportation and communications are opportunities to further strengthen U.S. global leadership in productive, innovative and sustainable agriculture, while boosting farm productivity and helping meet the Sustainable Development Goals.

Policies that advance trade agreements will also play a role in supporting farmer and rural livelihoods and keep prices of food and agriculture products affordable for consumers.

Invest in Public R&D and Extension

R&D funding levels authorized in the current farm bill account for less than one percent of all farm bill spending.[20] These funds support the U.S. Department of Agriculture's capacity to conduct research and development for sustainable production technologies, the economics of farming and agriculture systems and food safety and quality. They also provide the land-grant colleges and universities with human talent and research and extension support.

Experts say the USDA's annual research budget should be substantially increased from today's levels to reinvigorate the productivity growth rates of American agriculture and ensure future sustainability of the sector.[21] Current funding levels are inadequate to meet the need. R&D investments have a long gestation period and require sufficient and steady investments now to bear fruit in coming decades while reducing costs in future years for farmers and the food and agriculture industries.

The 2014 Farm Bill took a step toward this goal with the establishment of the **Foundation for Food and Agricultural Research (FFAR)**, a nonprofit corporation that supplements USDA's research investments by mobilizing matching private-sector funds. Public resources for FFAR leverage additional funding annually in public-private partnerships for cutting-edge research.

Additional funding for animal science research is urgently needed. Outbreaks of livestock diseases such as avian influenza and foot-and-mouth disease could devastate the industry, yet public research funding has been stagnant in real dollars for the past two decades.[22] **The next Farm Bill provides the opportunity to address the need for increased funding for animal science research and for a vaccine bank for high-consequence animal diseases.**

Embrace Science-Based and Information Technologies

Precision agriculture systems and crop and livestock biotechnologies have demonstrated their value in improving productivity and sustainability for farmers of all scales. New plant and livestock breeding technologies have the potential to deliver additional value and further enhance the sustainability of agriculture. Maximizing public and private agricultural R&D investments to bring more productivity and sustainability to farmers requires regulatory systems that work efficiently and regulators that are up to speed on the latest scientific advancements.

The regulatory system for biotechnology, which has not been revised since 1986, must be streamlined and modernized. Plants and animals derived from biotechnology and new breeding technologies should be assessed for potential health or safety impacts, rather than from the processes used to produce the trait or product. Without streamlined modern regulatory systems, innovation from small companies and universities may not reach farmers who need solutions from many different sources.

Enhance Private-Sector Involvement in Infrastructure and Agricultural Development

An efficient, well-maintained transportation infrastructure enables U.S. farmers to supply markets around the world, while keeping costs low for consumers. Yet the American Society of Civil Engineers estimates there will be a $5.18 trillion shortfall (in constant 2015 dollars) between now and 2040 in funding required to improve and maintain the nation's roads, railways, water and electricity infrastructures, airports, inland waterways and marine ports.[23]

Inland waterways and ports are the agricultural highways of America's Midwest. In 2015, 72 percent of U.S. agricultural export volume, valued at $128 billion, was transported to ports via waterborne commerce. The Inland Waterways Trust Fund and the Water Resources Reform and Development Act of 2014 provide significant federal resources for maintenance of waterways and ports, but still leave a $43 billion funding gap by 2040, which will result in delays, higher costs of products and inefficiencies.[24]

Current proposals for a new federal infrastructure initiative rely on significant funding from local, state and private-sector sources as well as from user fees. **These resources must be accompanied by a robust increase in federal funds for this essential public good, particularly in rural areas that are less likely to attract private-sector investments.**

Public-private partnerships are needed to extend broadband services to rural areas so that farmers have access to high-quality, high-speed fixed broadband and mobile cellular coverage for precision agriculture. Federal policies should incentivize the expansion of broadband infrastructure and services out to the croplands and ranchlands where farmers are deploying new, innovative equipment and data technologies. Policies should also protect existing spectrum uses by agriculture, ensure more spectrum is made available for commercial use, and reduce the red tape associated with building rural broadband networks.

The U.S. government, the insurance industry and farmers have collaborated to build an effective insurance safety net, which offers a variety of insurance products protecting farmers against price volatility, crop failures, pests and catastrophic events. In doing so, the need for costly, unpredictable disaster relief legislation has been all but eliminated. **The next Farm Bill should preserve this successful risk management tool and continue to offer a variety of insurance options to farmers at an affordable price.**

Expand Regional and Global Agricultural Trade

Trade agreements such as the **North American Free Trade Agreement (NAFTA)** benefit U.S. agricultural producers and their communities. Canadian and Mexican tariffs on U.S. farm products have been eliminated, and with the duty-free access and integration of trade standards, Mexico and Canada have become top purchasers of U.S. agricultural products. Annual U.S. agricultural exports to Mexico have risen by $13 billion since NAFTA was ratified.[25] It will be vital for U.S. farmers to retain a fair and well-functioning NAFTA trade agreement while seeking further trade facilitation improvements during its renegotiation.

After withdrawal from the Trans-Pacific Partnership Agreement (TPP), the U.S. is expected to lose agricultural market share across the Asia and Pacific region to competitors such as the European Union, making it even more important that NAFTA's tariff eliminations remain in place as it is renegotiated. **The U.S. also needs new trade agreements that enhance market access and lower tariffs on U.S. agriculture products** with countries like Japan and Vietnam.

Cultivate Partnerships for Sustainable Agriculture and Improved Nutrition

In response to the global food price crisis of 2007/2008, the U.S. dedicated significant new resources ($4.2 billion) toward a total global multilateral goal of $22 billion to boost agricultural development and food security in developing countries. Congress passed the **Global Food Security Act** in 2016 authorizing the **Feed the Future Initiative (FTF)**, which invests in agricultural productivity, food security and nutrition in select partner countries. FTF leverages resources from the private sector and from local and national governments to make the investments more sustainable. In 2015, FTF boosted the income of nine million producers by more than $800 million and reached 18 million children under the age of five with nutrition interventions.

To respond to the rising needs during the Great Recession, the U.S. increased funding for domestic nutrition programs, including **SNAP** (Supplemental Nutrition Assistance Program), **WIC** (the Special Supplemental Nutrition Program from Women, Infants and Children), the **National School Lunch and Breakfast programs** and **TEFAP** (The Emergency Food Assistance Program). These programs reduce food insecurity and improve nutrition for vulnerable consumers while benefitting farmers and food retailers. Innovative programs such as the **Food Insecurity Nutrition Incentives (FINI) Program** help low-income people purchase fresh fruits and vegetables at farmers markets.

Maintaining and leveraging these investments in global and domestic programs will support the achievement of the Sustainable Development Goals to eliminate extreme poverty and hunger.

Farming India's Future

Krishna and Gita own a five-hectare farm in Northern India's cotton belt. The farm has been in Krishna's family for generations and from a young age, Krishna helped on the farm and learned to love the land. But the farm struggled, and so did his family. Krishna considered leaving his village and looking for work in the city, but after seeing many friends and relatives fail to find steady employment, Krishna decided to stay and make his family's cotton farm thrive.

About 85 percent of the family's income comes from cotton. Krishna has increased the productivity of the farm by using improved cotton seeds and installing a drip irrigation system. The increased income has allowed him to hire additional labor and send their children to school. Gita has developed her own business growing tomatoes for local markets.

Krishna would like to expand his farm and use more mechanization, but as a younger farmer who didn't complete his secondary schooling, accessing affordable financing is difficult. Gita is concerned that the family relies too much on cotton for their income and wants to diversify by growing specialty vegetables that are popular in urban markets.

Creating a sustainable future for their farm and their family is the top priority for Krishna and Gita. They would like their children to have educational opportunities they did not, and to create a successful farming business that they could proudly pass to the next generation.

CULTIVATING INDIA'S "WHITE GOLD"

When Krishna began the transition to managing the farm from his father, the two biggest risks to his cotton crop were the quantity and timing of the annual monsoon rains and infestations of pests. It takes six to eight months for a cotton crop to reach maturity, which limits Krishna to two growing seasons each year. If one or both of those plantings are delayed or destroyed, Krishna loses a significant portion of his annual income.

As a young farmer, Krishna is open to trying new technologies and techniques, particularly for pest protection, soil erosion and water management. One of the greatest threats to Krishna's crop is the bollworm, a pernicious pest that feeds on cotton leaves and bolls. A single moth can lay thousands of pinhead-sized bollworm eggs. The bollworm larvae are barely visible until two or three days after they hatch. Pesticides begin to lose their effectiveness against the larvae after the fifth day, making it very difficult for farmers to stop an infestation once it starts.

To control bollworm infestations, Krishna's father would regularly spray their fields with pesticides, sometimes a dozen times or more in a single growing season, to preserve as much of the crop as he could. Over time, the bollworm became resistant to pesticide, so additional applications made little economic sense.

INDIAN FARMERS EMBRACE BT COTTON[1]

By 2013–2014, Indian farmers of all scales — including 7.7 million small-scale farmers — planted Bt cotton, accounting for 95 percent of the total cotton area planted, or 11.6 million hectares. Since its introduction, India's share of the global cotton market has grown from 12 percent to 25 percent, on par with China, the world's top cotton producer.

A review of **Bt cotton planting households** in India found that the increased income from cotton led to a **decrease in household food insecurity by 15 to 20 percent.** For each hectare of cotton planted, Bt cotton households consumed an **additional 74 calories per adult-size person per day; one-third of the additional calories came from nutrient-dense foods.**

India's cotton producers received a good price for their crop in the 2016–2017 growing season, especially compared to other commodity crops. Analysts expect at least a 10 percent increase in cotton production, as farmers move land out of soy and pulse production in anticipation of higher returns from cotton.

Krishna decided to plant a genetically modified cotton variety with built-in defenses against bollworm. Bt cotton contains *Bacillus thuringiensis* protein, which is toxic to the bollworm when ingested. The protein is not harmful to beneficial insects or to humans. With Bt cotton, Krishna uses significantly less pesticide, which reduces his input and labor costs and decreases the likelihood of runoff into watersheds.

During the 10 years that Krishna has planted improved cotton, his yields have increased by 35 percent and his pesticide use has decreased by 40 percent. The combination of increased yield and the savings from using less pesticide has improved the productivity and profitability of Krishna's farm. **Since its introduction in 2002, Indian farmers have seen an 88 percent increase in profitability, equivalent to $250 per hectare.**[2]

LAY OF THE LAND IN INDIA

With small plots of land and lack of training and credit, millions of marginal and small-scale farmers in India struggle to achieve productivity and sustainability on their farms. These farmers rely on wage labor and social safety net programs to supplement their farming income and food production. They invest less than $10 per year in productive assets for their farm, making it difficult for them to increase their productivity.

Only 15 percent of India's agricultural households cultivate more than two hectares (Figure 9A), but their farms account for 53 percent of the land area sown for crops (Figure 9B). Incomes from crop and livestock production, as well as investments in productive inputs like mechanization rentals and improved seeds, increase substantially among farmers cultivating more than two hectares. Medium and large-scale farmers earn more than 80 percent of their income from crop and livestock production.

Improving the productivity, livelihoods and nutrition of India's marginal and small-scale farmers is essential to the well-being of rural communities. At the same time, greater economies of scale must be developed in the agriculture sector if India is to sustainably meet its growing demand.

Figure 9A: Agricultural Landholdings by Plot Size in India (2011)

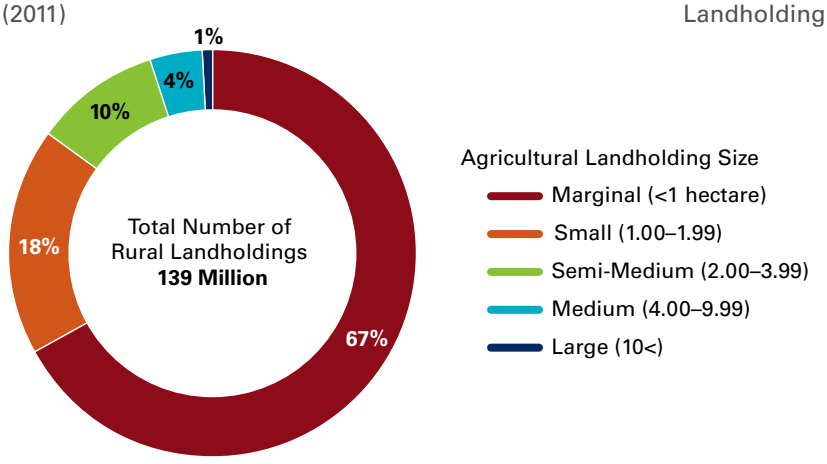
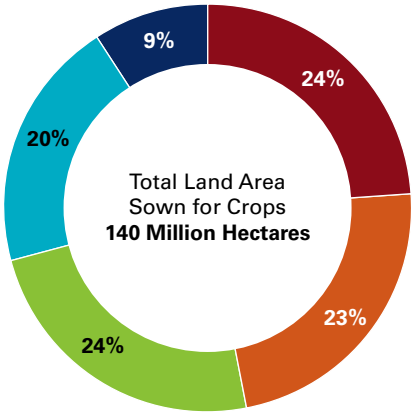


Figure 9B: Land Area Sown for Crops by Agricultural Landholding Size in India (2011)



» Of the 139 million total rural landholdings in India, 120 million are less than two hectares in size.

» Men control 86 percent of the agricultural landholdings; 14 percent are controlled by women.

» Farmers with less than 0.5 hectares earn twice as much money from livestock as they do from crop production.

» Marginal and small-scale farmers cultivate only 47 percent of the total land area used in crop production.

» 65 million hectares (52 percent of landholdings) are wholly or partially irrigated.

» 45 million agricultural households plant paddy rice as a major crop, with an annual average value of $405 per household.

Sources: India's Agricultural Census (2011) and national household survey data collected by the National Sample Survey Organization (2013).

Photo credit: Ruchi Narang/IFPRI

LEARNING TO GROW, GROWING TO LEARN[3]

To maximize his investment in Bt cotton, Krishna looks for advice on how to improve his cotton production practices. Government extension agents rarely come through his village, so he relies on advice from other farmers who are achieving good results. Krishna can also access agronomic, weather and market information from the company that produces his cotton seed.

Through radio programs produced by the state government, Krishna learned about the importance of leveling his fields to optimize water management and reduce erosion. In rural areas, farmers hire local contractors who use laser-guided leveling equipment attached to a tractor to grade the field. He also learned that cotton quickly exhausts the fertility of the soil, which can decrease yield. By rotating his cotton crops with pigeon pea and sorghum, Krishna restores the soil's nutrient content and produces nutritious fodder for his dairy cows.

Indian farmers say they are most likely to receive agronomic information through informal farmer-to-farmer knowledge sharing, private and non-profit extension services or radio and television programs. Contacts with government or university extensive programs are less common, according to a nationwide survey.

India's Agricultural University system (AU) was at its apex during the Green Revolution of the 1960s when the introduction of high-yield seeds for food grains triggered an explosion in agricultural yields, pulling millions out of hunger and poverty. In more recent decades, underinvestment in research capacity and human capital have resulted in a system that is not meeting the current demands and future needs of India's rapidly changing agriculture and food system.

The AUs need to improve their financial management and resource mobilization capacity. More than half of the AU faculty positions are unfilled, leading to overburdened faculty who have little time for research. The system is not graduating enough quality degree holders; the demand for degree holders in agricultural and related sciences outstrips supply by 14,000 people annually. Curricula are designed primarily to train students for public sector jobs, meaning graduates lack the skill sets most relevant for the private sector, where there are more available jobs.

In 2017, **The World Bank** approved a $82.5 million loan to the **Indian Council of Agricultural Research (ICAR)** for the **National Agricultural Higher Education Project (NAHEP)**, which seeks to transform Indian agriculture by investing in the people and systems responsible for developing and communicating new agricultural technologies and techniques.

NAHEP will award competitive grants to eligible AUs to finance the purchase of equipment for research or teaching, to restructure and strengthen their administrative capacity, to allow faculty to network and partner with other research institutions and the private sector and to create new experiential learning opportunities and job-placement programs. These human capital investments are the essential building blocks for a productive, sustainable food and agriculture system in India.

MECHANIZING FOR THE FUTURE[4]

Increases in productivity and income from Krishna's farm have enabled him to send their children to school and hire labor to help on the farm. Retaining hired labor is becoming more difficult for Krishna, especially as migration to urban areas increases. From 2005 to 2019, an estimated 58 million fewer people will be employed in agriculture, a decrease of 11 percent of the agricultural workforce.

Krishna would like to mechanize more of his operation. He pays a local farmer with a tractor to prepare the seedbeds, but planting, weed and pest control, and harvesting are done by hand. About 90–95 percent of India's cotton farmers have access to mechanization for seedbed preparation, but only 50 to 60 percent use mechanization for sowing or pesticide application and weed control. Cotton picking is done primarily by hand throughout India.

The Indian Ministry of Agriculture estimates mechanization improves farm yields by as much as 30% and reduces input costs up to 20%.[5]

India's small-scale farmers can achieve high yields, but their labor productivity is often very low. According to the Agricultural Machinery Manufacturers Association in India, the production systems for wheat and maize are the most highly mechanized. For cotton, mechanization is used primarily for seedbed prepation and pest control.

Krishna would like to own a tractor and planter, but commercial banks require significant capital and have short repayment periods. In the past, he borrowed money from relatives and local moneylenders, but he is wary of doing so for such a large purchase.

Custom Hiring Centres (CHCs) give farmers like Krishna affordable access to mechanization without having to own the machines themselves. Farmers can rent tractors and implements for soil preparation, seeding, application of nutrients and crop protection and harvesting. CHCs are centrally located to serve several villages, reducing the time and cost of transporting the equipment.

CHC partnerships include equipment manufacturers, such as **John Deere**, who provide the equipment, product service and training in agronomy practices and equipment usage. State governments contribute financial support and invest in infrastructure for the centres, as we all as in improvements for roads to ensure that equipment can be transported efficiently. Local entrepreneurs are hired to operate the centres, deploy and maintain the equipment as well as manage the contracts with the farmers.

The increased efficiencies generated by mechanization would give Krishna enough income to purchase a neighboring parcel of land that is being underutilized by its current owners. He could also move away from reliance on family and hired labor, which would increase his productivity and his income. In addition to growing more cotton, Krishna would like to add a small poultry business and purchase some additional dairy cattle.

LAND AND LABOR PRODUCTIVITY[6]

India's small-scale farms have enjoyed healthy yields thanks to the Green Revolution and continued improvements in seeds, crop protection products and access to fertilizers. Nevertheless, labor productivity on small farms is very low. Family members do the bulk of the farm work because mechanization rental and ownership is more expensive than family or hired labor.

Not only is this an inefficient use of labor, it contributes to high rates of rural poverty and food insecurity. For example, the income from a one-hectare farm, even if it is high-yielding, must meet the needs of as many as 12 people. As a result, small farmers are heavily dependent on food rations, wage labor and government support to supplement their farming incomes. Nearly 90 percent of farmers with less than two hectares participate in a government food ration program.

India has 120 million individual landholdings under two hectares. To meet its targets for reducing food insecurity and poverty, the government needs to invest in non-agricultural employment and skills training for rural workers to move more people out of agriculture, particularly manual labor, while fostering off-farm agricultural employment in jobs such as agro-dealerships, equipment and machinery maintenance, processing and storage.

Farmland consolidation can help achieve greater economies of scale as well. The necessity for consolidation is amplified by the growing competition for land. India's rapidly expanding manufacturing and service industries need room to grow and are already competing for land and displacing farmers across the country.

FINANCING A PRODUCTIVE FUTURE[7]

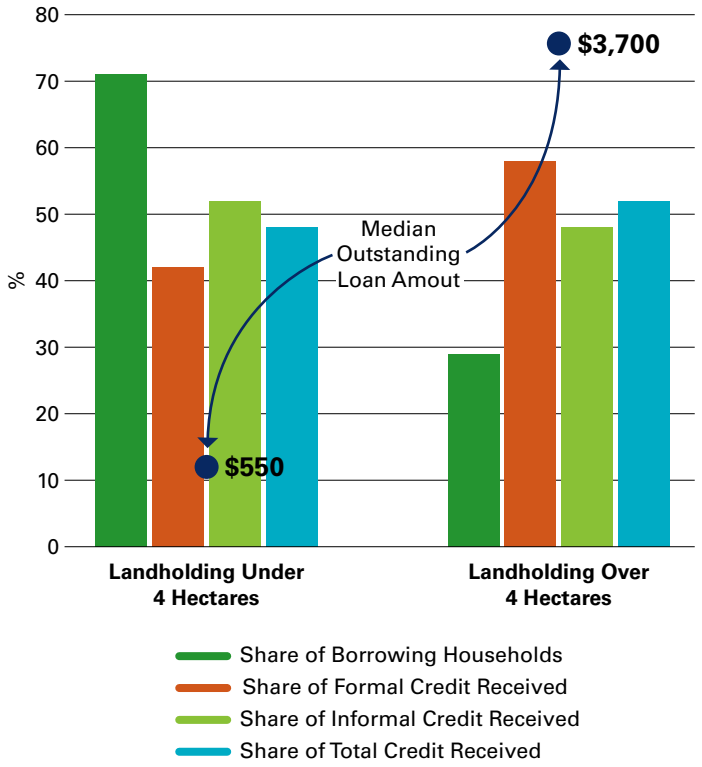
A national survey of agricultural households found that 52 percent of farmers tap into formal or informal credit markets; 85 percent of the credit is used to purchase inputs or to rent mechanization.

The surveys also reveal a positive correlation between credit and an increase in net farm income (NFI), with borrowers from formal institutions, such as banks or co-operatives, receiving a 17 percent higher rate of return than people who borrow from moneylenders or friends and relatives.

The link between institutional credit and higher NFI is largely due to the characteristics of formal borrowers who are more experienced farmers with higher educations and larger landholdings. They are also more likely to take advantage of government support programs and to seek out agronomic advice from public or private extension services.

The total amount of agricultural financing from formal lenders, such as banks and co-operatives, has increased four-fold in the last decade, but institutional credit still disproportionally benefits medium and large-scale farmers while most small and marginal borrowers rely on informal sources, which typically charge higher interest rates. Medium and large-scale borrowers also receive significantly higher loan amounts, as indicated by the median outstanding loan amounts in Figure 10.

Figure 10: Types and Sources of Loans to Agricultural Households in India



Source: Chart based on national household survey data collected by the Government of India National Sample Survey Organization in 2013.

WITH WATER, EVERY DRIP COUNTS[8]

Over his lifetime, Krishna has seen the monsoon seasons become more erratic and the droughts become longer and more frequent. Other than pests, Krishna sees weather as the greatest threat to the long-term viability of his farm.

India's annual monsoon rains provide 75 percent of the water used in agricultural production. Cotton requires less water than other staple crops, but the timing and quantity of the rains is critical. Cotton is planted before the first monsoon rains arrive in late June. If those rains are delayed, farmers may need to re-sow their crops or risk a significant decrease in yield.

> By 2050, India will use 1,450 cubic kilometers of water per year — 3 times the volume of Lake Erie in the U.S.[9]

To encourage farmers to improve their water management, the Indian central and state governments

THE CHALLENGE OF CLIMATE CHANGE FOR INDIA'S FARMERS[10]

The implications of climate change for India's agricultural economy, rural livelihoods and food security and nutrition are profound. Farmers are already struggling as India's temperature and rainfall patterns become hotter, drier and wetter.

By the end of the century, the mean summer temperature in India could increase by five degrees Celsius. The number of days of extreme heat could increase by more than a month and the number of warm nights could more than double. The amount of rain is projected to increase by as much as 40 percent, but the frequency of extreme rain events will also increase, as will the number and length of droughts.

Under these conditions, by 2035, yields for India's major food crops will decline by as much as 10 percent. Rising temperatures and the increase in extreme heat will make living and working conditions unbearable and reduce the productivity of farmers and agricultural laborers. Livestock will also struggle with the heat and the reduction in fodder.

Farmers can adapt to climate change through practices that increase their productivity and strengthen their resilience. Minimal tillage, intercropping and nutrient management improves the nutrient content in the soil. Water harvesting and drip irrigation conserve monsoon rainwater. Hybrid crops are bred to tolerate stressful conditions. Agronomic information, weather data and crop or livestock insurance help farmers manage the risks from extreme weather and market disruptions.

Without adaptation actions, agricultural productivity in India could decline by as much as 25 percent; the productivity of small-scale rain-fed farms could decline by as much as 50 percent. Adoption of climate-smart technologies and practices is still low across all farming sizes. Household surveys in Rajasthan found that medium-scale farmers with access to financing and agronomic training are more willing to try climate-smart agriculture practices, but marginal and small-scale farmers were more risk-averse and less likely to adopt new practices.

Even with widespread adoption of climate-smart technologies and practices, India's rural areas will experience significant hardship and socio-economic transformation as the climate changes.

offer subsidies to install micro-irrigation systems. The subsidies can range from 50 to 100 percent, but the application process is cumbersome and time consuming.

Farmers can purchase the equipment only after their application is approved, which in some states can take up to three years. Farmers and the micro-irrigation industry are urging the government to reform the program so farmers can install the equipment even as their application is going through the approval process.

Krishna and two neighboring farmers received subsidies to install drip irrigation systems. To save installation and maintenance costs, they decided to install a single system to serve all three farms, a total of 12 hectares. They built a 0.5-hectare pond to capture rain water. The pond is lined to prevent seepage and a filtration system removes debris and silt from the water. A network of pipes and valves moves the water to the fields, which are lined with narrow pipes that deliver water to each individual cotton plant.

Cotton needs 800 mm (31 inches) of monsoon rain, which is more than the 600 mm (24 inches) that have fallen in Northern India during recent monsoon seasons. With the drip irrigation system, this is more than sufficient rainfall for the three farms. Not only have yields on the farms increased, Krishna and his neighbors have added a second cotton rotation, which they were not always able to do when they relied on rain alone.

MANAGING RISK THROUGH DIVERSIFICATION[11]

As the productivity of Krishna's cotton crop has increased, so has his family's income, food security and nutrition. Krishna's wife Gita has used the additional income to pay for school fees, healthcare and food, particularly the fruits and vegetables she does not grow in her garden.

In addition to caring for her family and older relatives, Gita spends several hours each day working on the farm. She used to spend most of her time working in the cotton fields, but as the productivity of the cotton crop improved and the additional income allowed them to hire labor, Gita saw an opportunity to expand her backyard garden into an agricultural business.

Gita decided to grow and sell tomatoes, a staple in Indian cooking. She soon discovered that producing and marketing tomatoes for sale is more complicated than she first realized. Rather than using only manure and crop residue for fertilization, she added nitrogen and potassium to produce the size, taste and color of tomato that the market demands. She sells her tomatoes at her local *mandi*, the state regulated produce markets that buy from farmers at a pre-determined price and consolidate the products for sale to larger buyers.

Women farmers in India are growing "exotic" vegetables such as broccoli and cherry tomatoes for urban markets.

In a training session at her *mandi*, Gita learned how to "grade" her own tomatoes before bringing them to market. Fruit and vegetable farmers in Rajasthan reported that they realized higher prices through on-farm grading.

Selling to the *mandi* is convenient, but it does not have enough cold storage to keep fresh all the tomatoes it collects. If the tomatoes spoil at the *mandi*, then the farmer will be paid less once the tomatoes are sold.

Gita would like to sell directly to private buyers, but will need to increase her planting area, purchase more inputs and acquire storage equipment to make it economically viable. Gita sees her tomato business as an insurance against a failed cotton crop or drop in cotton prices. It also gives her an independent source of income that she can invest in the well-being of her family. Her family has been supportive of the tomato business, but when it comes to investing in inputs and equipment or allocating land and labor, the cotton crop still takes priority.

Someday Gita would like to expand into "exotic" produce, such as cherry tomatoes, broccoli, red cabbage or cucumbers. India's rapidly growing middle class has developed a taste for fruits and vegetables that are more commonly found in Western or Southeast Asian cuisines. As the number of restaurants serving international food has grown, so has consumer interest in cooking these dishes at home. The market for exotic produce is growing by 15 to 20 percent per year. More than 80 percent of the demand is being met through imports, so Gita could take advantage of this new market opportunity.

FORTIFYING AGAINST HIDDEN HUNGER[12]

Micronutrient deficiency is a hidden form of hunger that can have devastating consequences for physical and cognitive development and disease prevention. **Nearly half of the people in the world with micronutrient deficiencies live in India,** particularly in the country's rural areas. About 75 percent of children under three have iron deficient-induced anemia and five percent of children under five are zinc deficient. These deficiencies will cause lower work productivity and decreased immunity to disease as they age. According to a review by the Indian Council of Medical Research, the annual economic impact of micronutrient deficiency in India is as much as 2.4 percent of GDP.

Fortifying staple foods such as wheat, milk or edible oils with micronutrients is a cost-effective way to increase nutrient intake in large populations. The **India Integrated Food Fortification Project led by the Global Alliance for Improved Nutrition (GAIN)** has worked with food processors and the government of Rajasthan to fortify wheat flour, milk and oil with iron, folic acid and vitamins A, D and B12. GAIN provided technical advice on the fortification process, equipment purchases, quality control and distribution. More than 4,500 metric tons of wheat flour, 8,900 metric tons of oil and 4,100 metric tons of milk are being fortified each month and purchased by or distributed to nearly 15 million people.

BARRIERS TO FRUITFUL TRADE[13]

India is the second largest producer of fruits and vegetables in the world after China. Between 2009 and 2013, Indian agricultural exports such as mango, bananas, onions and pomegranate increased at an average annual rate of six percent.

Despite the impressive growth in exports, India still struggles with excessive loss and waste in the supply chain, a lack of farmer knowledge about safety and quality standards and an inability to trace products back to their source to ensure safe production and storage protocols.

India has a highly localized food system, especially for fruits and vegetables. Most farmers are cultivating less than four hectares and selling to the local *mandi*, which distributes to a vast informal network of 15 million *kirana* stores, the small family-owned retail outlets where most Indians purchase their food.

The short domestic supply chain from farm to *mandi* to *kirana* to table is critical given India's insufficient cold storage network, which has only enough capacity for 10 percent of the perishable food produced. To close this gap, **India's cold storage and transportation network needs to increase its capacity by 61 million metric tons at an investment of more than $10 billion,** not including annual costs for management and maintenance.

Global value chains have much higher standards for safety and many governments and global retailers are insisting on traceability — the ability to access all the information regarding the production and handling of the food they purchase, all the way back to a specific farmer's field.

A World Bank review of the spice and horticulture trade in Kota Division in the state of Rajasthan identified several areas for improvement and investment. The current Warehouse Receipts Systems responsible for regulating and ensuring the safety of the food supply chain needs to be strengthened and expanded. Better coordination and education of the various actors in the food sector needs to be improved. Collaboration with farmer organizations will help reduce fragmentation and streamline the value chain. Investment incentives for the private sector would increase the capacity of the cold chain.

REFORMING AGRICULTURAL MARKETING IN INDIA[14]

India's state-sponsored *mandi* system facilitates the purchase and sale of agricultural products from farmers to consumers, retailers and food processors. Farmers are required to sell their products to the *mandis* and cannot sell directly to wholesalers or private retailers.

This restriction has created substantial hardship for small-scale farmers. By law, farmers should be paid the day they bring their product to the *mandi*, but traders often delay payments, sometimes for months, until they sell the product. If the product spoils before the trader sells it, that loss is reflected in the payment the farmer receives.

Farmers are rarely paid more than 30 percent of the final retail price. Without access to private markets, they have little choice but to accept the price they are offered at the *mandi*. Some states, such as Rajasthan, are reforming their *mandi* system and allowing farmers to sell certain products, usually fruits and vegetables, directly to private buyers. Additional reforms are necessary to improve the fairness and efficiency of the *mandi* system; access to private markets also needs to be expanded and encouraged.

Photo credit: Vaishali Dassani (IFPRI)

Private-Sector Partnerships Foster Agricultural & Community Development in India

Partnerships between the public sector, private enterprise and communities allow the participants to share the risks, responsibilities and benefits of their joint investments. They offer an effective way to increase agricultural productivity and improve the nutrition and livelihoods of small-scale producers.

Photo credit: The Mosaic Company Foundation

BALANCED CROP NUTRITION BOOSTS INCOMES AND EDUCATION

Since 2008, the **Mosaic Villages Project**, a collaboration between **The Mosaic Company, The Mosaic Company Foundation** and implementing partner, the **S M Sehgal Foundation**, has helped Indian farmers move out of poverty and achieve greater food security. Mosaic's investment includes funding and the expertise of Mosaic agronomists who work alongside local partners to train farmers in balanced crop nutrition and agronomic best practices.

In the remote districts of Mewat and Alwar in Rajasthan, the **Krishi Jyoti Project,** or "enlightened agriculture", helps farmers improve productivity of three crops: pearl millet, wheat and mustard. The project focuses on five key aspects of agricultural production: soil health, seed and fertilizer, water management, agronomic training and market linkages. Village leaders selected farmers representing all castes and landholding sizes to participate in the program.

With balanced crop nutrition practices — using the right mix of macro- and micro-nutrients to meet the needs of the crops and soils — together with agronomic expertise and financial support, **farmers increased yields by as much as 35 percent over traditional farming practices.** In total, Krishi Jyoti has directly benefited more than 26,000 farmers across 60 villages and boosted cultivation across nearly 16,000 acres of land. **Average income per acre has also grown between 4,480 Rs ($70 US) for wheat to 5,760 Rs ($90 US) for mustard.**

Communities participating in the Krishi Jyoti Project are using the additional income to help create a better life for future generations. The S M Sehgal Foundation and Mosaic funded renovations for 20 schools in Alwar, Mewat and Sonipat — including adding sanitation facilities, safe drinking water systems and school kitchens.

Photo credit: Monsanto Company

Photo credit: John Deere India

HELPING INDIA'S FARMERS AND COMMUNITIES RISE

Since 2010, **Monsanto Company** has worked to develop the agronomic skills of small-scale farmers in India. The **FarmRise™ — Mobile Farm Care** program is a mobile digital platform used by farmers who plant maize, cotton and vegetable seeds. Currently there are more than four million farmers enrolled in this service in India.

The FarmRise™ platform enables farmers to communicate by phone or text with a trained expert in their local language for free. If the problem cannot be solved over the phone, a FarmRise™ advisor will visit the farmer within 24 hours. Farmers also receive texts with the latest price information from nearby markets and regular alerts on how to respond to changing weather conditions. Farmers do not need a costly smartphone to participate; basic cellphone technology is sufficient to take advantage of FarmRise™ services.

Monsanto India is committed to community development, as well as to agricultural development. Lack of **safe drinking water** is one of the major contributors to malnutrition in India, particularly for children. Contaminated water causes chronic diarrhea, which prevents the body from retaining nutrients. As a result, children experience stunted growth (too short for their age), which leads to life-long physical and cognitive impairments.

To help address this issue, Monsanto India's Vegetables Team has **helped 20 villages install water purification systems.** To access the water, community members pay a minimal amount using a pre-paid ATM-like card. The funds are used to maintain the purification system.

COMMUNITY TRANSFORMATION THROUGH MECHANIZATION

John Deere India is partnering with **Madurai Non-Formal Education Centre (MNEC)** to help small-scale rice farmers in the village of Thenkarai near Madurai in the state of Tamil Nadu transition to an integrated mechanized approach that saves time and labor while improving rice yields and incomes.

In 2015, the project coordinators conducted interviews with village members and other stakeholders, a process that revealed several barriers to mechanization: a large supply of free or cheap labor, the high cost of equipment, a lack of training and a resistance to change.

To overcome these barriers, six farmers were selected to manage a 10-acre demonstration plot using the new approach, including machine transplantation, soil testing, water management, nursery preparation and weed and pest control. At the demonstration farm, a dedicated program manager instructs and trains local farmers in mechanization and agronomy practices.

The farmers have seen reductions in input and labor costs, and they have optimized their water usage. With the proper use of mechanization, **yields have increased by 40 percent per acre.** Seed use has decreased by 30 percent and weeding time is reduced due to proper herbicide usage. One village leader said, "People from nearby villages keep asking us how we got **2.75 metric tons of rice per acre.** This is a proud thing for us."

John Deere India and MNEC also support the holistic development of the community. They have upgraded the school infrastructure and study materials. They also provide tuition support for local children. To help generate new livelihood opportunities, skills development courses are offered in tailoring, goat rearing, mushroom cultivation and cosmetology.

Policy Priorities for Improving Productivity and Sustainability in India

Invest in Public R&D and Extension

India has one of the largest public agricultural research systems in the world, but it has been consistently underfunded. The human capital of the Agricultural University system needs to be strengthened: thousands of faculty positions are unfilled and not enough qualified graduates are being produced to meet demand from the public and private sectors. The National Agricultural Higher Education Project, a joint initiative of the World Bank and the Indian Council of Agricultural Research, addresses several of these issues. It needs to be accompanied by reforms and investments to ensure the research, development and extension system is an effective, efficient public good.

Embrace Science-Based and Information Technologies

The success of Bt cotton in India has demonstrated the value of improved seed technologies to farmers of all scales and to the Indian economy. Indian farmers could benefit from GMO technologies for other crops, especially cereals and horticulture, but none has been approved for sale thus far. India's regulatory and legal frameworks for advanced seed technologies, including those related to intellectual property, need to be stabilized to encourage additional private investment in the biotech industry.

Enhance Private-Sector Involvement in Infrastructure and Agricultural Development

Increased collaboration between the public sector, private enterprises and producers is needed so more farmers can access mechanization and financing. Expanding the Custom Hiring Centre model, where farmers rent tractors and implements, would allow many marginal and small-scale farmers to increase their productivity at an affordable price. Programs promoting bank and co-operative financing for marginal and small-scale farmers need to be scaled-up significantly and paired with training to help them improve their business skills and creditworthiness.

Cultivate Partnerships for Sustainable Agriculture and Improved Nutrition

Childhood stunting (low-height for age) in India has decreased from 48 percent to 38 percent in the last decade and child underweight rates have declined from 43 percent to 38 percent.[17] The principal factors contributing to this decline are improvements in women's education levels, an increase in the marriage age and access to electricity, safe drinking water and sanitation. Public-private partnerships to expand diet diversification, fortification of processed foods and biofortification of staple crops will help India take the next significant step in reducing malnutrition in all its forms.

Foster Capacity for Regional and Global Trade

The most significant constraints to small-scale farmers entering export markets are distance from trading centers and the education level of the farmers.[18] Phytosanitary standards and traceability requirements are strict and vary from country to country. In addition, multi-national companies impose private standards for sustainability and labor practices. Connecting India's small-scale farmers to international markets requires capital investments in the road and rail networks, as well as in the cold chain. Farmers wishing to enter international markets need significant training in food safety, storage and grading protocols.

For more on policies and investments to support agricultural productivity in India, see GHI's 2014 GAP Report® at www.globalharvestinitiative.org.

Urban Consumers Transform the Global Food System

More than half of the global population lives in medium and large-size cities, a trend that is accelerating in many parts of the world. In addition, average incomes in urban areas are rising, and with that so is the demand for a wider range of high-quality food and agricultural products.

These products cross many borders as they are grown, processed, packaged and sold. Asian consumers eat U.S. pork and farmers there feed their cattle corn and soybeans grown by American farmers, while Asian countries provide much of the seafood and fruit juice that is consumed in the U.S. In Africa, consumers wear clothes manufactured in China with cotton grown in India, while the shelves of Europe's urban supermarkets are stocked with spices from Africa and coffee from Latin America.

As food and agriculture has become increasingly globalized to meet growing demand, consumers around the world remain concerned about the price, safety, quality and sustainability of what they eat and what they wear.

Chinese Urban Consumers — Choices and Concerns

Shen Nianzi's parents were farmers who in 2000 moved to an urban area. Today she lives with her husband and son in a fast-growing city in southeast China. Her husband prefers to eat chicken and pork, but over the past several years, thanks to an increase in their income, they have begun to eat more beef and dairy products.

Like many of her friends who are urban consumers between the ages of 20-35, Shen Nianzi shops at a modern retail food store and wants to purchase more vegetables to provide healthy meals for her family. In 2017, the Chinese government launched its second 10-year healthy lifestyle campaign, urging consumers to eat less fat, salt and sugar and aim for "a healthy diet, healthy weight and healthy bones."[1]

Shen Nianzi is also concerned about rice and other food crops that may have been grown in contaminated farm soil, so she is willing to pay more for trusted brands that she knows are high-quality and safe. That is why, since the birth of her son, she has been favoring foreign brands of food and childcare products in her trips to the grocery store.

She is by no means unusual. China's rapid economic growth is leading to a much greater focus on food safety and nutrition among consumers, with more than 82 percent of people like Shen Nianzi now willing to pay more for foods they know are higher quality, more nourishing and lacking undesirable ingredients. This compares to the global average of 68 percent who are willing to pay for such foods.[2]

African Urban Consumers — Price and Selection

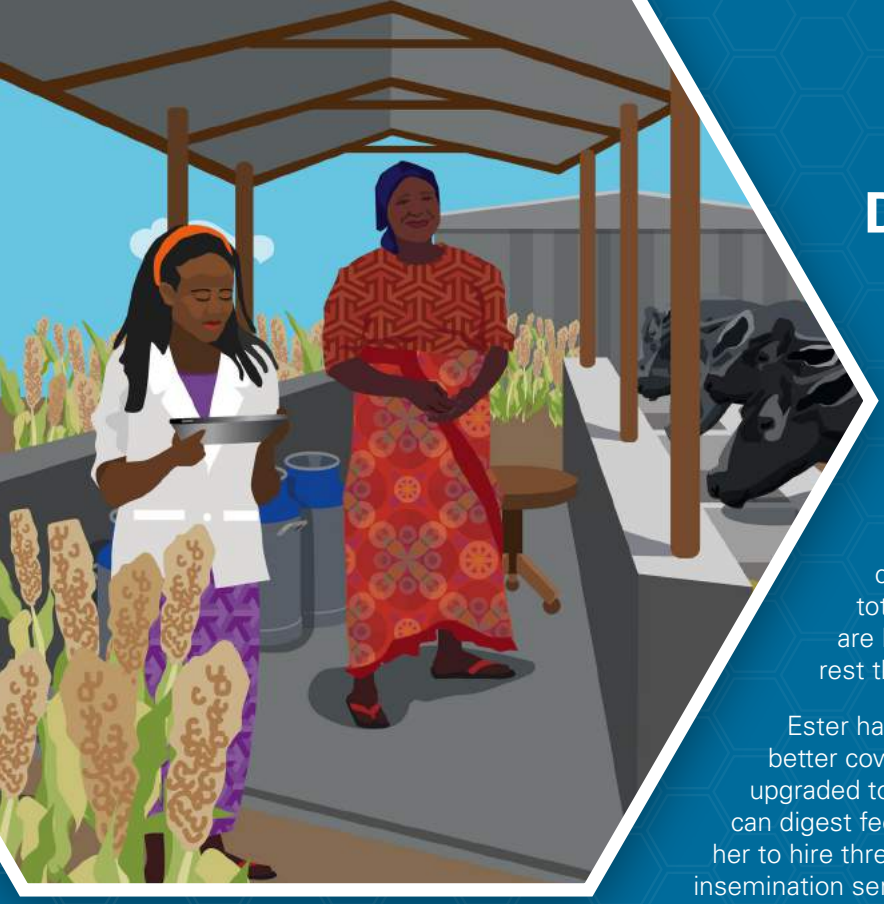
Mercy is a recent university graduate who works and lives in her hometown of Nairobi. While she keeps an eye on her household budget, she is willing to spend more on high-quality food and occasionally splurges on specialty items from different parts of the world.

Growing up, Mercy's family purchased food at several small stores and local markets. Nairobi had supermarkets, but they were on the city's outskirts, so the family never shopped in them. Recently, however, a supermarket opened in Mercy's neighborhood and it has become her preferred place to buy groceries.

Mercy likes the prices and the diverse selection of items available at the supermarket. Nairobi consumers identified low prices and a large selection of items as the reasons they prefer supermarkets to smaller retail outlets.[3]

Urban consumers also see many of the premium food products offered by supermarkets as affordable luxury items, especially the varieties of fruits, vegetables, meat, fish, spices and packaged items that are not typically available in African markets. Demand for premium products, even for staple foods, is also strong: 70 percent of the rice consumed in African cities is high-grade premium rice.[4]

While this growing demand for premium grocery products is currently met through imports, it also offers an enormous opportunity for African farmers and processors to profit and grow their businesses by expanding their productivity and capacity to deliver value-added foods.



Dairy Drives Development in Kenya

Ester is a successful dairy farmer in Nandi County in the Northern Rift region of western Kenya, home to 47 percent of the country's dairy production.[1] Through a local women's dairy co-operative, she was inspired to develop her own dairy business. She has 15 head of cattle (one bull, 10 cows and four calves) producing a total of 105 liters (28 gallons) of milk per day; 10 liters are kept for consumption and calving and she sells the rest through her co-operative.

Ester has invested in the productivity of her farm by building a better cowshed with dedicated milking and feeding stations. She upgraded to high-grade dairy cattle that are more productive and can digest feed more efficiently. Increasing her milk output enabled her to hire three full-time employees and pay for veterinary and insemination services. To protect herself from risk, Ester purchases livestock insurance, grows her own fodder and saves a portion of her income in a personal bank account.

Ester has moved out of poverty and has attained financial independence. Yet for all her success, Ester knows she is vulnerable, particularly to illness and old age. She fears that someday she will be unable manage the farm, even with the help of her employees, and she will have to sell some of her cows or land to survive. Her savings will not be enough to live on if she becomes chronically ill or disabled.

A DAUGHTER'S INSPIRATION

Dalmani, Ester's daughter, admires her mother and wants to help other women have the same opportunities to improve their lives. She is studying agriculture and seed science at the university, focusing on dryland crops.

The drylands of northeastern Kenya have the highest rates of rural poverty in the country along with the highest incidence of hunger and malnutrition. The lack of water and the short cropping season restrict farmers to fast-growing, heat-tolerant crops such as sorghum and millet.

Dalmani is studying how sorghum and millet can be improved to increase their resistance to heat and disease, and how these crops can be biofortified with essential nutrients like vitamin A, zinc and iron to help reduce the incidence of micronutrient deficiency.

She sees great potential in these improved crops, but knows from her mother's experience that widespread adoption of new technologies by farmers requires training and support. She hopes to be an educator as well as a scientist and thereby help bridge the gap between the researchers developing new technologies and the people who use them.

The East African Dairy Development Project (EADD) aims to provide sustainable livelihoods and food security for one million dairy farmers in Kenya, Uganda and Tanzania by 2018. Heifer International leads the project, which helps farmers establish producer organizations (PO) so they can access inputs, credit, training and a market for their milk. They also learn preventative health practices and receive veterinary medicine. Photo credit: Russell Powell, courtesy of Heifer International

AFRICA'S DAIRY HUB[2]

Kenya's dairy farmers produce more than five billion tons of milk per year, the most in Africa. The dairy industry accounts for six to eight percent of Kenya's GDP and provides income for two million households. Consumers also benefit from Kenya's dairy productivity; per capita milk consumption is 100 liters (26 gallons) per year, more than any other developing country.

Annual milk output in Kenya grew from 66.3 million tons in 1963 to 5 billion tons in 2014.[3]

Kenya has two distinct dairy value chains. The **formal value chain** consists of highly-productive medium and large-scale farms (more than three hectares, with at least 10 cows) focused on commercial production. Milk yield is at least 10 liters (2.6 gallons) per cow per day. Farmers in the formal value chain have cross-bred and high-grade dairy stock, make on-farm investments and have access to credit. They have access to an extensive cold-chain network with large-scale pasteurization capacity capable of processing 3.5 million liters (920,000 gallons) of milk per day. Compliance with quality and safety standards in the formal value chain is high, making it the principal source of milk for urban consumers and value-added dairy products.

The **informal value chain** accounts for 70 percent of the milk that is sold in Kenya. Small-scale producers with one to three cows and a farm size of less than three hectares produce milk primarily for their consumption and local sale. Input and technology use is low and milk yields average seven liters (1.8 gallons) per cow per day. Raw milk is sold directly to consumers through an extensive network of informal traders. The cold-chain network is limited and adherence to quality and safety standards is minimal.

WOMEN IN DAIRY — ESTER'S STORY[4]

With 15 cows, Ester is considered a medium-scale farmer and part of the formal value chain. She sends her milk to the co-operative where it is tested for safety and quality, chilled and sold in bulk to commercial buyers.

Membership in the co-operative is critical to Ester's success. She receives training in animal health practices, business management and product handling. Through the co-operative, Ester obtains veterinary

and insemination services, loans to improve her farm and purchase equipment and livestock index insurance which reduces the risk to her income from cattle accident, death and disease.

The fees for the co-operative services and financing are deducted from the payments she receives for her milk. The payments go directly into her **M-PESA account**, a phone-based mobile payment system used by two-thirds of adults in Kenya. Ester has a bank account for her savings, but she uses M-PESA for daily money management, including payroll.

The payment system is efficient, but Ester's co-operative often waits until the milk is sold before paying its farmers.[7] As a result, she is sometime short of cash, making it difficult for her to pay her workers on time.

To improve her cash flow and reduce costs, Ester grows two hectares of *brachiaria* grass as the principal source of feed for her cattle and to sell in the rapidly growing fodder market. The nutritious grasses are easy for cattle to digest, which improves their milk productivity and reduces the amount of methane they produce during the digestive process.

Demand for improved grass and legume fodder from small and medium-scale farmers is skyrocketing. Ester sells her *brachiaria* at the local "fodder store," which purchases and sells fodder for farmers in the area.

The International Center for Tropical Agriculture (CIAT) has developed brachiaria grass varieties that are drought-resistant and increase milk productivity in dairy cows by 40 percent. Photo credit: Georgina Smith/CIAT

A SHARED-VALUE INVESTMENT IN ANIMAL HEALTH[5]

Africa is home to 20 percent of the global dairy cattle population, but produces only five percent of the global milk supply. This inefficiency in milk production has implications for Africa's efforts to reduce hunger and malnutrition and to reduce the environmental footprint of livestock production. It also indicates the widespread need for improvement in animal health practices and expanded access to veterinary medicines and knowledge.

In Kenya, 80 percent of milk output comes from small-scale producers. Farmers with smaller herds and fewer resources are less likely to have access to veterinary care. **Elanco Animal Health**, with support from the **Bill and Melinda Gates Foundation**, is launching the **East African Growth Accelerator (EAGA)**, an initiative to help small-scale farmers in Kenya, Tanzania and Uganda improve the health and productivity of their dairy herds and poultry.

To ensure a sustainable livelihood and earn sufficient incomes to invest for the future, small-scale dairy farmers need consistently healthy, productive herds. Good animal care and feeding practices promote productivity and prevent disease, but access to affordable, quality animal health care products is also essential. EAGA will use a shared-value approach, providing farmers with affordable access to the products they need.

CONSTRAINTS FOR PRODUCTIVE GROWTH[6]

Milk production is labor-intensive. In addition to the daily feeding and milking of the cows, dairy farmers must constantly manage manure, monitor the health of the animals and maintain milk safety and quality standards established by the co-operative. Ester finds it difficult to retain skilled workers. Her employees require constant supervision, which makes it difficult for Ester to attend to other activities. To reduce labor time and costs, Ester plans to purchase milking equipment and milk testing technologies. She hopes this will attract reliable employees interested in working with the new technologies.

Ester is also concerned about the health of her cattle and their exposure to diseases. Part of her county is infested with tsetse fly, the biological vector of *trypanosomiasis* (sometimes called sleeping sickness), a parasitical disease that causes anemia and emaciation in cattle. The condition is chronic and if left untreated, it is often fatal. If a cow survives the infection, its milk productivity can drop by

Boran cattle are well-suited to the dryland areas of East Africa, but produce very little milk and meat compared to cross-bred and high-grade varieties. The International Livestock Research Institute (ILRI) farm in Nairobi is breeding Boran cattle that efficiently digest the low-quality grasses and silages that are common to the drylands. This will decrease methane emissions and improve milk and meat productivity. Photo credit: International Livestock Research Institute (ILRI)

30 to 40 percent. Trypanosomiasis is a zoonotic disease that is passed between animals and humans via the tsetse fly, although the number of human cases in Africa has dropped substantially due to sustained public health efforts.

KENYA'S CLIMATE CHALLENGE[7]

Kenya's leadership in Africa's dairy industry is endangered by climate change. A substantial increase in mean temperature is predicted for East Africa and could lead to a reduction in fodder output and grazing land capacity.

Increasing temperatures threaten the health and productivity of livestock. As droughts lengthen and intensify, large-scale cattle losses are likely. Small-scale farmers will be forced to sell cows or land to cope with the loss of income, making it difficult for them to recover financially when the drought is over.

As part of its climate change adaption and mitigation strategy, **Kenya's dairy sector needs to increase the productivity of its dairy cattle and reduce the GHG emission intensity of milk production.** Sub-Saharan Africa's milk production has the highest emission intensity in the world, three times greater than the global average, and almost double that of South Asia.

Kenya is home to 75 percent of the dairy cattle in Southern and Eastern Africa; 80 percent of Kenya's milk output is produced by small-scale farmers. By improving cattle productivity and reducing emission intensity, the dairy sector in Kenya can significantly mitigate greenhouse gases while increasing small-scale farmer income.

More than half of the emission intensity of milk production in sub-Saharan Africa comes from methane produced during a cow's digestive process. One strategy for reducing these emissions is to add legume silages to a cow's diet. Legumes are digested more efficiently, so a cow produces less methane and more milk.

Improving the genetics of dairy cattle is another way to reduce methane emissions and increase milk productivity. Kenya has already made strides in this direction; the country is home to more than 70 percent of the cross-bred and high-grade dairy cows in Africa. Sixty percent of the milk produced in Kenya (three billion liters) comes from high-grade cattle and cross-breeds. But high-grade dairy cattle are more susceptible to disease than local cattle varieties, so breeding for disease resistance is a top priority.

The drylands of northeastern Kenya are particularly vulnerable to climate change. This region receives less than 500 millimeters (20 inches) of rain per year and has fewer than 90 plant growth days. Many of the people in this region are pastoralists, moving regularly to find forage for their livestock

The **U.S. Agency for International Development (USAID)** funded the **Resilience and Economic Growth in Arid Lands-Accelerated Growth (REGAL-AG)** program to accelerate sustainable growth in the drylands by strengthening market linkages and developing livestock service and input markets. The program implementer, **ACDI/VOCA**, has constructed or renovated 12 livestock markets. The Merille Market in Marsabit County is close to the main road and easily accessed by livestock producers, traders and services providers. It has a large sale yard, animal pens, an animal health center, hay store and retail selling area. It serves as the economic hub for the 5,000 families who live in the area.

DuPont's Africa Regional Technology Center in Delmas, South Africa. This is one of the facilities in DuPont's Africa Research Hub that produces an industry-leading multi-crop product portfolio for the continent. Photo credit: DuPont/Barbra Muzata

SEED SOLUTIONS TO MEET AFRICAN FARMERS' NEEDS

Farmers around the world need seeds that give them better yields, adapt to changing weather and soil conditions and provide protection against pests and disease. **DuPont** has a network of research facilities that develops varieties and traits to improve yield, weather tolerance and disease resistance.

In 2017, **DuPont opened the Africa Regional Technology Hub** to accelerate the development of seed products that meet the specific needs of African farmers and comply with government regulations in the region. The Hub will focus on maize, sunflower, soybean and drybean crops.

The Hub is comprised of several research facilities, including the Delmas Technology Center, which focuses on research activities in Eastern Africa, a multi-crop drought research center in Hoogekraal working on drought tolerance and Africa's biggest private Insectary, where the DNA of crop pests can be studied and stored. DuPont also has a biotechnology partnership focusing on the development of biofortified sorghum, which improves Vitamin A, zinc and iron content of the crop in popular local varieties.

The Insectary will be critical to the development of traits to combat local yield-robbing pests, some of which are unique to the continent. The DNA and dispersal patterns of pests can vary across geographies, so seed traits that effectively combat the pest in one region may not work in another. For example, the fall armyworm, which has destroyed the crops and livelihoods of millions of maize farmers in Africa, has a different genetic code than its relatives in other parts of the world. At the Insectary, researchers will have the resources to develop traits specific to African pests, which may help protect crop yields in the future.

Taking It to the Farmer

In addition to developing targeted seed varieties, DuPont is working with international donors and African partners to provide small-scale maize farmers with seeds, agronomic training, postharvest storage and access to markets. In Ethiopia, the **Advanced Maize Seed Adoption Program (AMSAP)** has reached 250,000 farmers in just four years, more than double the original five-year projection. Farmers have experienced productivity increases of 300 percent.

To help farmers process and store their increased maize output, AMSAP has installed shellers and storage units in 16 villages and built new grain warehouses that have reduced postharvest losses.

The AMSAP program is being replicated in other countries, including the Zambia Advanced Maize Seed Adoption Program (ZAMSAP), which launched in 2015. In Solwezi, Zambia, farmers compare maize grown from hybrid seeds to maize grown from open pollinated varieties. Photo credit: Ann Steensland/GHI

Policy Priorities for Improving Productivity and Sustainability in Kenya

Invest in Public R&D and Extension[8]

Kenya has made significant investments and structural improvements in its national agricultural research system. In 2014, Kenya invested $274 million (in 2011 dollars) in public agricultural research and development, a 36 percent increase from 2004. While the creation of the Kenya Agricultural and Livestock Research Organization (KALRO) in 2014 consolidated several commodity-focused research institutions into a single, coordinated research system, it faces funding and capacity shortfalls that threaten to reduce its effectiveness. Government funding for agricultural research flatlined in 2011 and donor investment levels are diminishing. With many of the country's agricultural scientists retiring in the coming decade, developing and retaining the next generation of researchers needs to be a top investment priority.

Embrace Science-Based and Information Technologies[9]

At current rates of TFP growth, Kenya will meet only 11 percent of its food demand in 2030 through productivity growth. The economic, environmental and human consequences of low productivity are evident in Kenya's maize yield which is just 30 percent of the global average. To increase their output, Kenyan farmers are opening new lands for agricultural production, but prolonged drought and a widespread infestation of armyworm have reduced maize output by 50 percent, putting millions at risk for hunger. An open, science-based policy dialogue is needed to ensure that Kenya's farmers can access a range of tools and technologies, including traditional hybrid and genetically modified seeds that are drought-tolerant and pest-resistant, to meet the productivity and sustainability challenges they face.

Enhance Private-Sector Involvement in Infrastructure and Agricultural Development[10]

Farmer co-operatives and producer organizations play a critical role in Kenya's dairy sector, creating economies of scale and supporting the development of a dairy value chain that produces more milk than any other country in Africa. Policies that encourage private-sector investment in the transportation infrastructure and the nationwide network of milk cooling centers would reduce milk losses and increase farmer incomes. Reforms are also needed to support the efficient and fair management of the co-operative system and to incentivize co-operatives to increase leadership opportunities and training for women, who comprise 50 to 75 percent of dairy co-operative membership but hold less than one third of the leadership positions.

Cultivate Partnerships for Sustainable Agriculture and Improved Nutrition

Partnerships between the public sector, private companies and producers are needed to help integrate Kenya's small-scale agricultural producers, traders and retailers into the national value chain, which is essential to meeting the country's goals for reducing hunger, malnutrition and poverty. Several examples from the livestock sector illustrate how this can be achieved, including the East African Dairy Development project (see page 49) and the work of ACDI/VOCA to construct livestock markets in the drylands (page 51). But the scale of these programs is small when compared to the scope of the challenge. Scaling-up and replicating successful efforts is essential, along with sustained financial commitment to support it.

Foster Capacity for Regional and Global Trade[11]

In a regional analysis of trade capacity in East Africa, Kenya had high marks for trade facilitation and transparency. Kenya scored well for the extent of automation and external agency cooperation, as well as for the availability of regulatory information and documentation requirements and the presence of an appeals process to dispute customs decisions. But the country's primary contribution to the global agricultural value chain is raw materials such as coffee, tea, fruits and vegetables. Increasing Kenya's capacity for value-added agricultural production would boost export opportunities and help meet in-country demand for high-value agricultural products.

Diversifying for Resilience in Vietnam

Minh and Trang grow rice on two hectares (five acres) of land in the **Mekong River Delta** in Vietnam. Their two children, ages 8 and 12, attend school and help their parents cultivate the rice fields. Like many people in Vietnam, rice provides two-thirds of their family's daily calorie consumption, and they rely upon it for cash income as well.

In recent years, Minh and Trang have struggled with the declining productivity of their rice as the salinity of the water has increased in the river delta region. Like their farming neighbors, they incorporate shrimp production alongside their rice fields, helping them earn more income. But they continue to face environmental challenges to their farming operations from flooding, drought and increasingly polluted water sources.

CLIMATE CHALLENGES IN THE RICE BOWL

The Mekong River flows through the vast **Mekong River Basin (MRB)**, which includes parts of China, Myanmar, Laos, Thailand, Cambodia and Vietnam. More than 70 million people live in the MRB and rely on the Mekong River for drinking water, agriculture and transportation.

The Mekong River empties into the **Mekong River Delta** spanning 13 provinces in southern Vietnam. The river delta is home to 19 percent of Vietnam's population (17.5 million people) and produces 57 percent of the country's rice and 41 percent of its aquaculture products.[1] Farmers in this region also grow fruit and other agricultural products, making it the breadbasket and rice bowl of Vietnam.

Vietnam is now the world's second largest rice exporter after Thailand, and the river delta is key to this success story; 90 percent of all exported rice from Vietnam comes from the Mekong River Delta.[2] But rice and agricultural productivity are threatened by changes in climate and shifting weather patterns.

With its flat terrain averaging less than one meter above sea level, this region is vulnerable to encroaching salt water from the surrounding sea. Since 1985, the sea water level has risen by an average of three millimeters annually, spreading further inland and impacting a wider area each year.

Rainfall levels are also increasing and timing of the rains is shifting. Farmers must now adjust their growing practices to account for the decreased rainfall at the start of the rainy season and higher rainfall amounts at the end of the rainy season.[3]

Upstream dams in the Mekong River Basin, coupled with changing ocean temperatures in the Pacific due to El Niño–Southern Oscillation (ENSO, an irregular periodical variation in winds and sea surface temperatures), contribute to higher salinity and drought in other sections of the delta. Taken together, these shifts threaten the region's food security and environmental sustainability. Farmers and food producers must adopt new practices and innovative technologies to adapt and survive.

PRODUCTIVE RICE FARMS BEAT CLIMATE CHANGE

The International Rice Research Institute (IRRI) and **DuPont Pioneer** conducted research in partnership to develop a commercial Pioneer® brand rice hybrid seed (PHB71) that prospers in soil with higher salinity.

Bringing together a female rice parent line developed at IRRI's research center in the Philippines with a male parent line developed by Pioneer has resulted in a hybrid with improved roots, rigorous growth to make it through a shortened growing season and yields that are 30 to 40 percent higher than seeds that self-pollinate in open fields (open-pollinated varietals, or OPVs). These enhanced seeds are also proven to be more resistant than local varieties to diseases such as bacterial leaf blight and leaf blast.

Agronomic training helps farmers effectively incorporate these improved hybrids into their regular farming practices and to receive the most value from them. In Vietnam, the **Thanh Hoa Province Department of Agriculture and Rural Development** has partnered with **DuPont Pioneer** to establish a **Rice Model Farm Program** where farmers learn about seed selection, management of soil

Farmers in Vietnam learn about optimal rice spacing and planting and sustainable rice farming practices at the Rice Model Farm.

health, pests, water and nutrients and sustainable farming practices to improve productivity. They also are trained in postharvest storage strategies to prevent losses.

As part of the model farm program, farmers grow the hybrid seeds side by side with their local varieties to test and learn together about their advantages. PHB71 has been proven to help farmers across many countries in southeast Asia who face similar soil salinity challenges from rising sea levels.

The Vietnamese government is providing new options for farmers to improve their agricultural practices and grow diverse, higher-value crops. While they face risks by adopting new practices, Minh and Trang know they must bolster their farm's resilience in the face of climate change and shifting market demands.

Trang has decided to focus on improving the productivity of her rice fields and is working to produce higher quality rice. In addition, she and Minh adopted a rice-shrimp rotation system promoted by the government in 2000, enabling them to double their annual income.

In the rice-shrimp system, shrimp are raised during the dry season (February to June) and rice is grown in the rainy season (August to December). Trang relies on wet season rainfall to flush the salinity from the soil during the period between harvesting the shrimp and planting the rice.

Since 2010, higher temperatures and shifting rain patterns have increased the salinity of her soil, reducing the yields of her rice. Recently, Trang learned of a new rice seed developed through a public-private partnership that grows more effectively in saline soils, and she is receiving training on how to incorporate this rice variety through a rice model farm training program.

Catching shrimp in a rice-shrimp field in Vietnam. Photo credit: Kam Suan Pheng, 2011. WorldFish

NURSERIES CULTIVATE HARDY SHRIMP

In addition to boosting their rice productivity, Trang and Minh have benefitted from public-private partnerships to improve the quality of their shrimp production.

In Vietnam, 90 to 95 percent of the area under shrimp production and 65 percent of production volume originate with small-scale farmers like Trang and Minh.[4] The future of shrimp production in Vietnam depends heavily on fostering their knowledge and use of best practices to boost sustainable productivity.

The Vietnamese shrimp industry must improve the quality of shrimp stock available for farmers and train them to select good quality post-larvae shrimp for their growing operations. Accessing better quality shrimp and protecting them during the vulnerable early growth stage will result in healthier, hardier, better-quality shrimp, bringing producers higher prices with less wasted feed and water resources.

Trang participated in a training course on how to select high-quality post-larvae shrimp and how to construct a shrimp nursery where young shrimp can be fed with approved nutritious starter feed. This boost in the early stage of their life cycle helps shrimp grow more quickly to full weight and size, as well as become more resilient to sudden water stresses from salinity or temperature changes.[5]

The training was sponsored by the **United States Agency for International Development (USAID)**

BETTER RICE FOR BETTER NUTRITION

In Vietnam, rice is the main food for millions of poor people. Rice provides caloric energy but is deficient in micro-nutrients such as iron, vitamin A, iodine and zinc, putting them at risk for devastating diseases and even death.

Globally, as many as **19 million pregnant women are vitamin A deficient (VAD), along with 250 million pre-school age children.** An estimated 250,000 to 500,000 of these children become blind every year, half of them dying within 12 months of losing their sight.[6]

To improve rice quality while maintaining high yields, plant breeders and agronomists from governmental and international research agencies are collaborating to develop biofortified rice (varieties with higher levels of iron, zinc and beta-carotene for vitamin A) through breeding and through genetic modification.[7]

Small-scale farmers can grow, sell and consume this higher-value rice while earning more income and improving their nutrition. These rice varieties can be marketed through regular commercial outlets and will benefit low-income, rice-dependent people.

The International Rice Research Institute (IRRI) is the coordinating institution for research centered upon improving the nutritional content of rice through biofortification.[8] IRRI coordinates the research for **Golden Rice**, in which rice is biofortified by transferring genetic material from corn and a common soil microorganism into the rice plant so that the plant contains beta-carotene. The body converts beta-carotene in Golden Rice to vitamin A as it is needed. Daily consumption of one cup of Golden Rice could supply 50 percent of the Recommended Daily Allowance of vitamin A for an adult.

Studies to date show that food and livestock feed derived from biofortified rice is as safe and nutritious as that derived from conventional rice varieties.

Improving diets through diverse food consumption, vitamin and mineral supplements and food processing can help people suffering from micronutrient deficiencies, but these interventions have ongoing costs and industrial processing may not be readily available in developing countries.

Biofortification is a sustainable solution because the new and improved seeds can be available through government or commercial markets, enabling farmers to continue doing what they do best: cultivate and harvest improved, high-quality rice.

Vietnamese farmer, Huynh Van Hue, enjoys a successful corn harvest.

CORN FEEDS VIETNAM

Corn is already the second largest crop in Vietnam after rice, yet **the country still imports between five and seven million tons of corn each year to feed livestock** for growing consumer protein demand.[9] With little additional land available for production, farmers must improve corn productivity on existing land to seize the market opportunity to supply livestock feed.

Better production practices and better seeds are needed. As part of **Monsanto Vietnam's** sustainable development efforts, more than 200,000 farmers have received training since 2015 on good agronomic practices and hybrid corn seed selection. Seeds with beneficial traits improved through conventional breeding and advanced biotechnology are now becoming available for many farmers in Vietnam.

High-yielding improved corn seeds such as DEKALB® hybrids and stacked trait biotechnology (seeds engineered for both insect protection and herbicide tolerance) help farmers grow more while requiring less labor to remove weeds and apply crop protection. The improved corn is particularly resilient against three harmful pests: asian corn borer, common cutworm and corn earworm.

To help farmers make the transition from rice to corn, Monsanto agronomists and rice farmers developed a series of best agronomic practices, the **Dekalb® Cultivation Rice-to-Corn Rotation Protocol,** that was selected as a preferred cropping system by the **Vietnamese Ministry of Agriculture and Rural Development.** Farmers in pilot programs used this protocol across several departments of Vietnam and increased their incomes by up to 400 percent while supplying more corn for livestock feed. New jobs and businesses such as corn drying and feed mill development are becoming part of the growing corn value chain.

The Ministry has set a goal of transitioning 668,000 hectares of rice-growing land to corn production in the northern region of Vietnam by 2020. Farmers in other regions of the country are also being supported as they diversify to more resilient, high-value crops and livestock while sustainably intensifying rice production in the most suitable areas.

and tested as part of a pilot project by local organizations including the **Vietnam Red Cross**. Aspects of the initial pilot project will now be shared across five provinces in the Mekong Delta, covering 250,000 hectares of rice-shrimp farmland and benefitting one million people who rely on this system for their income.

FROM RICE TO CORN: DIVERSIFYING FOR RESILIENCE

While rice consumption and rice farming is culturally important across Southeast Asia, some farmers can no longer earn enough income from rice farming to support their families. At the same time, the demand for corn across the region, including Vietnam, is soaring.

Vietnamese Ministry of Agriculture and Rural Development (MARD) policy encourages production of high quality and specialty rice where land is most suitable, along with support for farmers to transition to different crops, such as corn, on land where rice cultivation is less productive.

Minh noted this rising demand and decided to diversify his farm production to include corn. Taking advantage of government laws that reformed land tenure and improved access to land for small-scale farmers in the south of Vietnam after 1993, he now rents two additional hectares of land from a neighbor in his village who no longer wishes to cultivate rice. Minh uses government-approved agronomic protocols disseminated through training workshops to make the shift to corn production on this land.

Minh and Trang are further diversifying by planting salt-tolerant trees (guava, papaya and mangrove) along the banks of their rice fields and shrimp ponds to provide additional food and income, while stabilizing soil and, in the case of mangroves, helping filter water. Diversification to corn, shrimp and fruit trees has increased their incomes while also diversifying their own diets.

Policies to Improve Productivity and Sustainability in Vietnam

The Vietnamese government began modernizing its agriculture sector in the 1980s, focusing on reducing food insecurity and poverty. In 1990, 45 percent of Vietnamese people were undernourished, compared with 11 percent in 2015, a significant achievement in the wake of war and reconstruction.

According to the **Global Food Security Index**, Vietnam has improved food security by implementing nutrition standards, establishing food safety net programs for vulnerable populations and increasing access to finance for farmers. The government has also helped reduce food loss and the proportion of the population in poverty, while stabilizing the "booms and busts" of agricultural production.[10]

Much of this success has been driven by sound government policies and investments in the agriculture sector. Since 1986, the government policy ("Doi Moi", or socialist-oriented market economy) has reformed the collective model of agriculture, recognizing farming families as the main units of agricultural production instead of cooperatives and state farms. Land reform after 1988 allowed farmers to lease land for up to 20 years. Vietnam rapidly moved from insufficient levels of rice production to become the world's second largest rice exporter today after Thailand.

Further modernization and policy reform will help Vietnam realize its full agricultural potential while improving food security and reducing poverty, particularly for 67 percent of the country's population who live in rural areas.

Invest in Public R&D and Extension

To achieve high levels of agricultural productivity growth, global development institutions recommend allocating **at least one percent of agricultural gross domestic product (AgGDP) annually to public agricultural R&D** — indeed, this figure has become a key a measure of agricultural research intensity. While the Vietnam government's agricultural R&D expenditures more than doubled between 2000 and 2010, **research spending as a percent of agricultural GDP was just 0.18 percent in 2010, among the lowest in the developing world.[11]**

In June 2014, the government approved the **Agricultural Restructuring Plan (ARP)**, which focuses on increasing the productivity, innovation, diversification and quality of Vietnam's agricultural products and sector. The ARP invites broader stakeholder participation, especially from national and international private-sector partners, and supports the core institutions that service agriculture.

In light of this strategic shift towards modern agriculture, the Vietnamese government must increase its budget support for R&D and extension to strengthen the resilience of small-scale farmers facing the challenge of climate change.

Embrace Science-Based and Information Technologies

The Vietnam government currently embraces biotechnology to improve resilience of crops to disease and increase yield, particularly for rice and corn, as well as to improve the health of shrimp and fish in aquaculture systems.

A prominent technology being explored is the multiplication of disease-free citrus trees using shoot-tip grafting techniques. With this technique, Vietnamese scientists have created a species of citrus trees tolerant to the citrus greening disease that is devastating citrus crops worldwide.

Innovative technology such as genome-editing is new to Vietnam, but agricultural scientists are interested in these applications, especially to improve rice and cassava in the face of climate change.

Vietnam has in place clear and consistent biosafety laws that provide a legal framework for the safe management of genetically engineered organisms and products.

The government has established intellectual property regulations that protect the rights of plant variety developers.

The Ho Chi Minh City government is seeking investment partnerships to create a high-tech agricultural zone and a biotechnology center that will promote urban agriculture to feed its rising population.

Enhance Private-Sector Involvement in Agriculture and Infrastructure Development

In 2017, Vietnam began significant policy reforms that enhance private-sector involvement in agriculture and infrastructure development. Vietnam mobilizes capital investments from foreign direct sources, governments and international development institutions to augment its own investments in infrastructure and agriculture.

Land reform is a critical step to attract investment capital and, in 2017, land laws continued to liberalize so that farmers and agricultural businesses can achieve economies of scale. Access to credit and financing for agricultural companies and entrepreneurs is becoming further streamlined. New strategic policy guidance by the Ministry of Agriculture also improves collaborations with international agricultural companies and services.

In the Mekong Delta, the government is inviting domestic and foreign investors to explore agricultural business opportunities and is eliminating cumbersome barriers to private-sector partnerships. One such project led by the city of Can Tho seeks a $26 million investment to build the Thoi Hung High-Tech Agricultural Zone on 500 hectares of land. The facility will produce plant varieties, breed livestock under international standards and apply cutting-edge technology in processing agricultural and aquatic products.

Vietnam also recognizes that foreign investments and partnerships must be mobilized to modernize its irrigation systems and cold-chain infrastructure for agricultural storage and transport to urban areas.

Cultivate Partnerships for Sustainable Agriculture and Improved Nutrition

Vietnam attracts investments and partnerships with international development institutions such as the World Bank, the International Fund for Agricultural Development, The Asian Development Bank, the U.S. Agency for International Development and the government of Japan in order to promote economic development, food security and nutrition. More partnerships to improve the productivity and sustainability of agriculture are needed, particularly with private-sector agriculture and food industries, to address the impact of climate change and to improve the quality and safety of the food produced in Vietnam.

Many private-sector agribusinesses find a stable and reliable partner in the people and government of Vietnam. The government facilitates partnerships for productive value chains in aquaculture, coffee, corn, fruit and rice, along with many other commodities, and provides opportunities to add value and branding opportunities to Vietnamese agriculture.

Foster Capacity for Regional and Global Agricultural Trade

Agriculture and food producers reap greater benefits from their exports when countries facilitate cross-border trade. Reducing bottlenecks at the border also helps reduce food loss and waste. Vietnam's performance in trade facilitation is better than many Asian and other lower-middle income countries. Areas requiring improvement include streamlining of border procedures through automation and modernization of information systems and appeal procedures to allow goods and services to flow in a timely manner.[12]

Vietnam maintains an open and consistently-enforced regional trade approach with its Southeast Asian partners through the **Association of Southeast Asian Nations (ASEAN)**. ASEAN member countries have made significant progress by lowering intra-regional tariffs to less than five percent and have harmonized many standards for food and agriculture products.

With the halt of the regional **Trans-Pacific Partnership (TPP)** trade agreement due to the withdrawal of the United States in 2017, Vietnam now looks to Europe to realize new opportunities for trade. **The EU-Vietnam Free Trade Agreement (EVFTA)** will accelerate trade between Vietnam and individual EU states and is expected to be ratified in 2018. The EVFTA will most likely be the first agreement between EU states and a Southeast Asian nation, allowing Vietnam to serve as the premier entry point to the region for goods and services. Vietnam's export standards must conform to those of the EU for most goods, including food and agricultural products. This will require ongoing improvements in sustainability and food safety.

Cultivating Agriculture and Peace in Colombia

Doña Rosa and **Don Julio** live on their ranch in a mountainous area of rural Colombia where they raise 90 cattle for both meat and milk.

Weather patterns have changed over the past decade, making their livestock and farm more vulnerable to drought and heat. To build resilience, Rosa and Julio are now transforming their farm into a **silvopastoral production system (SPS)** through a partnership with the government, conservation organizations and farmer cooperatives as well as technical assistance providers. Changing production systems is a risk, but they hope it will improve their livestock operation, their land and their way of life.

Rosa and Julio employ several workers who are returning from years of displacement during Colombia's 50-year conflict and who help them care for their cattle and land. Almost seven million people were displaced during the war and some 87 percent come from the countryside.[1] Rosa and Julio are increasing their incomes, creating employment and protecting the natural resource base while cultivating peace in Colombia.

LATIN AMERICA AND COLOMBIA: AN OPPORTUNITY FOR FARMS TO FLOURISH

With abundant natural resources and increased political and economic stability in many countries, the **Latin America and the Caribbean region (LAC)** looks to agriculture as a key opportunity to feed its expanding middle-class and become a breadbasket to the world. Agricultural productivity growth on the continent has skyrocketed in recent decades and the region is now beginning to shift toward lower-carbon, environmentally-friendly agriculture systems.[2]

Despite this progress, difficult issues must be addressed. Conserving forests and biodiversity while improving livestock productivity in Latin America will be key to cultivating a successful sustainable agriculture system.

While Latin America produces more beef than any other region, emissions from beef production are the second highest in the world after South Asia. Nearly one-third of Latin America's beef sector emissions come from land-use change for pasture expansion.[3]

The problem is acute in **Colombia**, one of the world's top cattle-producing countries with 23 million head of beef and dairy cattle. Cattle production uses 38 percent of Colombia's total land area,[4] with 80 percent of all agricultural land in Colombia used for pasture.[5] Decades of civil conflict have exacerbated forest and biodiversity loses, with some three million hectares (7.4 million acres) of forest destroyed.[6]

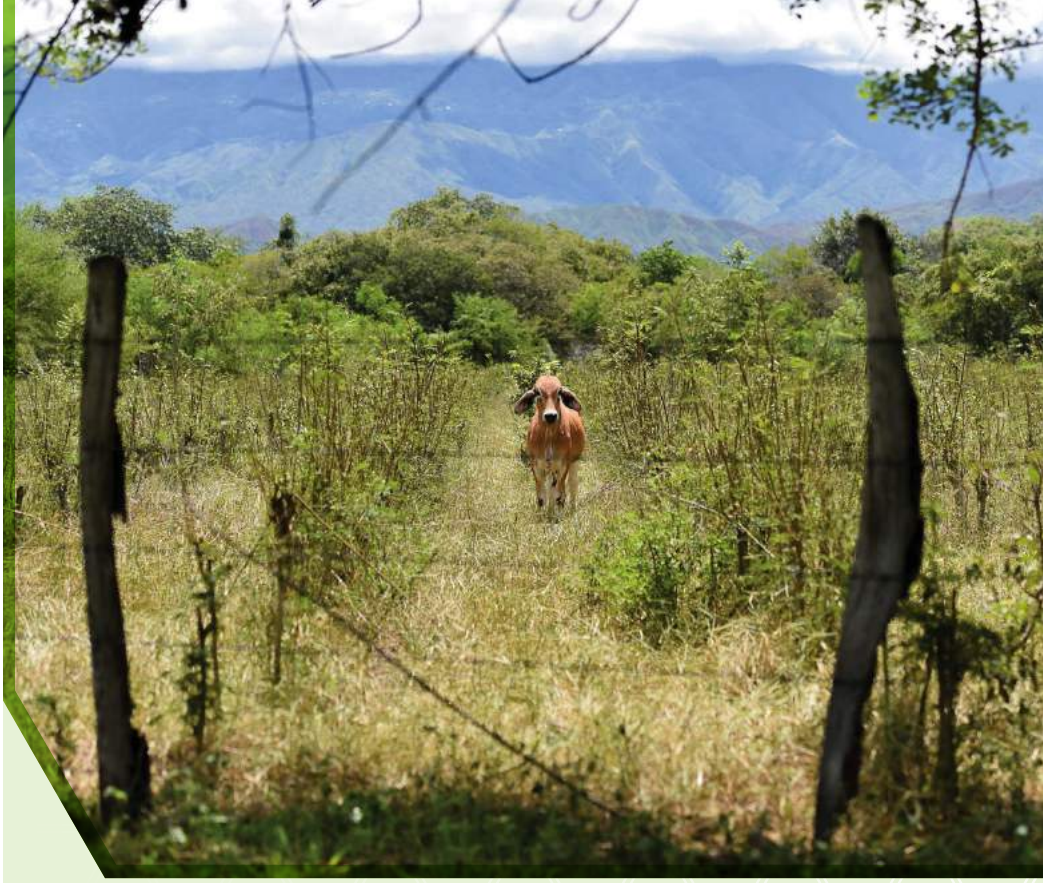
Colombia faces a challenge in helping its small and medium-scale farmers shift to sustainable lower-carbon cattle production systems that use less land, conserve more forests and provide higher incomes. But with the end to the civil war and the possibility of stability and peace, Colombia is attracting new sources of investment from both the public and private sectors to begin this transition in the coming decade.

Through the years, Doña Rosa and Don Julio struggled to manage 90 cattle on their ranch of 60 hectares (150 acres). Their cattle grazed on grasses and shrubs for forage across the ranch, but spells of searing heat and the poor quality of the forages reduced their cattle's health and productivity.

In 2007, their region suffered a severe drought, during which they, along with many ranchers in their region, lost significant numbers of cattle. After this, Rosa and Julio worked with their local cattle trade association and the national **Colombian Cattle Ranching Association (Federación Colombiano de Ganaderos, FEDEGÁN)** as well as a Colombian sustainable livestock foundation **(La Fundación Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria, CIPAV)** to implement a more resilient form of livestock production: the silvopastoral production system (SPS).

With technical advice from CIPAV's SPS experts, Rosa and Julio and their two employees began planting trees, shrubs and new grasses in their pastures. Using fodder shrubs like *leucaena* and grasses like *brachiaria* boosts the nutrition of the forages for their cattle, allowing them to gain weight and produce more milk and meat in less time.

Trees provide shade for their cattle, protecting them from heat. And with more vegetation in the pastures, the soil retains nutrients, water and carbon, making their ranch more resilient to cyclical drought.



Rows of fodder shrubs interspersed with grasses and trees characterize silvopastoral systems. Photo credit: Neil Palmer, CIAT

CULTIVATING SUSTAINABLE PASTURES

Silvopastoral systems consist of fodder shrubs planted at high densities and intercropped with grasses and trees planted in rows. The land is divided into plots and animals are rotated from plot to plot every five or six days.

Shrubs such as the *Leucanena leucocophala* are high-protein fodder for cattle. They grow rapidly, which makes them well suited to silvopastoral systems. These shrubs also fix nitrogen to soil and reduce erosion.

The Center for International Tropical Agriculture (CIAT), based in Cali, Colombia, safeguards one of the largest and diverse tropical forages collections, with more than 700 species from 75 countries. From this collection, CIAT breeders have developed improved *brachiaria* grasses with high nutritional value that are more easily digestible for cattle and reduce the level of methane per liter of milk produced. The deep roots of these grasses also prevent soil erosion and they can be integrated into silvopastoral systems globally.

The SPS system benefits ranch workers as well. Workers on Colombian and Mexican SPS farms with good animal welfare and environmental impact reported they liked the work, increased their environmental awareness, gained new skills and stayed in the job longer than conventional farm workers.[7]

FOSTERING THE TRANSITION TO NEW WAYS OF FARMING

Rosa and Julio have benefited from the Colombian government's new focus on stimulating productivity in the livestock sector. Colombia's recent **National Development Plan** (2010–2014) proposed reducing the total land used for livestock by 21 percent by 2030 and FEDEGÁN, the national cattle ranching association, proposes similar pastureland reduction goals along with productivity increases.

But making the transition is not easy. It requires technical training for ranchers like Rosa and Julio as well as some initial costs until the system can be established and until farm profits increase to repay the investments made. It also requires a change in mindset. Many ranchers perceive forestry and cattle ranching as incompatible practices and often clear forested areas so that cattle can graze on grasslands. Ranchers also fear that by using less pasture and conserving more forests, they risk losing some of their farmland to the government or other ranchers.

As a first step, Rosa and Julio worked with the Ministry of Agriculture and Rural Development to formalize the ownership of their land through secure title, helping them gain greater access to finance and to certify that they did not gain land through deforestation.

Next, they participated in a multi-stakeholder pilot program that provided a low-interest loan and technical assistance to convert to the silvopastoral system. After just two years, the higher productivity of their operation allowed them to sell more milk and bring more meat to market quickly, increasing their profits by 18 percent annually and repaying their loan after only eight years.

Improving their beef quality has allowed Doña Rosa and Don Julio to enter into an agreement with a large Colombian supermarket chain, **Grupo Éxito (Almacenes Éxito SA)** to supply beef for the growing consumer market in Colombia. Grupo Éxito is a significant purchaser of locally-raised beef from small and medium-scale ranchers. They are exploring systems that would allow them to purchase zero-deforestation beef, similar to their agreements with coffee growers.[8]

As most consumers in the Colombian context still view price as the primary driver of their purchasing decisions, ranchers like Rosa and Julio must become increasingly market-oriented and provide higher-quality meat and milk while reducing their production costs to compete with international beef suppliers.

MESA GANADERIA SOSTENIBLE COLOMBIA

A ROUNDTABLE FOR ACTION

The idea for **Colombia's Sustainable Livestock Roundtable** emerged in 2013 in recognition of the need to consolidate the technical knowledge necessary to advance the country's sustainable livestock production.

Four years later, this group of 31 public and private sector organizations — representing producers, businesses, academia, research and public institutions, as well as international organizations providing technical cooperation — is actively working to develop public policies, programs, plans and projects for boosting sustainability in the livestock value chain.

With the **Inter-American Institute for Cooperation on Agriculture (IICA)** serving as its general secretary, the Roundtable has formed three commissions and related working groups to focus on institutional strengthening, policies and

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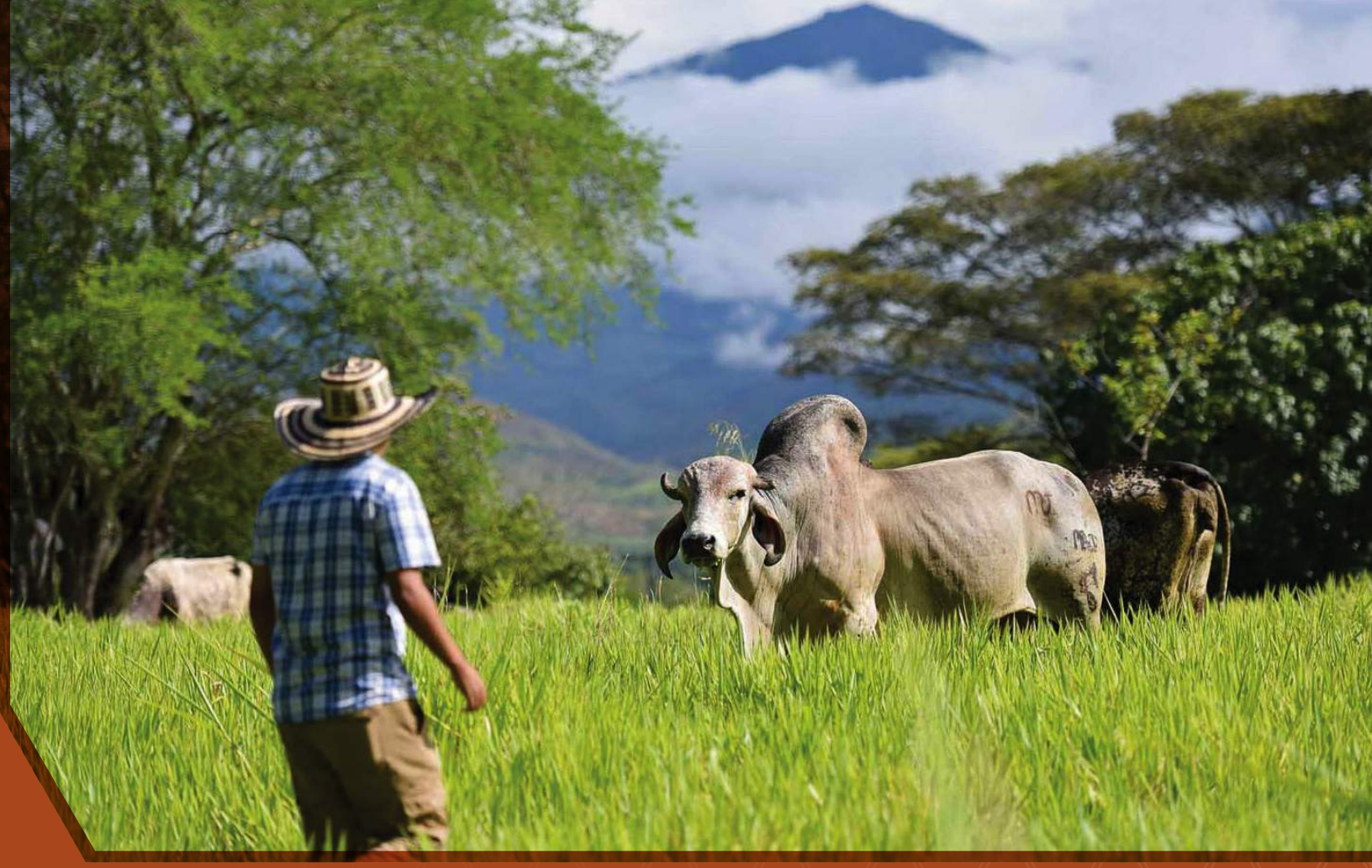

Photo credit: Neil Palmer, CIAT

WORKING WITH RANCHERS TO MAKE BEEF SUSTAINABLE AND PRODUCTIVE

With funds provided by the **Global Environmental Facility** and the **United Kingdom Energy and Climate Department,** the **Colombian Cattle Ranching Association (FEDEGÁN)** and conservation organizations such as **The Nature Conservancy** and other partners are helping more than 2,600 small-scale farmers and ranchers through the **Colombian Sustainable Cattle Project.**

To date, the project has converted 9,307 hectares (23,000 acres) to silvopastoral systems. Another 37,000 acres of forest has been taken out of production through conservation agreements with farmers and ranchers.

Many of these ranchers now receive payment for ecosystem services (a financial incentive to adopt sustainable practices and set aside conservation areas on their lands) as part of the initiative.

Participating ranchers report more productive soils, along with improved soil carbon retention and greater biodiversity on their farms. They also support more cattle per hectare as well as a 10 percent average increase in their milk and meat production.[9]

> The project has reduced greenhouse gas emissions by more than two million tons, the equivalent of taking 1.4 million passenger automobiles off the road for one year.

With the involvement of experienced stakeholders and successful implementation and repayment of loans and new sources of funding the project can serve as a model that reaches larger numbers of Colombian ranchers in the coming years. The Nature Conservancy is working to expand these practices across Latin America, demonstrating that agriculture and natural habitat can work hand in hand to preserve the planet while increasing production to feed a growing world.

planning, and socio-economic aspects including markets across the livestock value chain.

The Roundtable has hosted international exchange initiatives with industry colleagues from Australia, Brazil, Costa Rica and Mexico, and it has identified a set of sustainability criteria to help define and identify the geographic areas most suitable for livestock production. Seven technical workshops have been held on topics such as markets, communication and zoning to develop the capacities of the various actors along the value chain.

It is also developing a database to inform market studies, to analyze consumer demands and to develop agreements to reduce deforestation in the meat and milk value chains. Another goal is to adapt certification protocols for sustainable livestock systems in the different regions of the country.

With its 34 offices and long-standing presence in the Americas, IICA supports coordination and delivery mechanisms such as the Colombia Sustainable Livestock Roundtable. Together many actors are united to strengthen institutions and develop capacities that increase the sustainability of agri-food systems while promoting productive low-emissions development.

LATIN AMERICA AND COLOMBIA TAKE AIM AGAINST CLIMATE CHANGE

In Latin America, the agricultural sector must play a central, strategic role to achieve the international climate change commitments these countries made under the historic Paris climate change agreement reached in 2015.

To share and improve their climate change mitigation and adaptation strategies for the agricultural sector, representatives from Colombia's **Ministry of Agriculture and Rural Development** and its **Rural Agricultural Planning Unit** recently participated in a regional exchange with agricultural and environmental ministries and agencies from five other South American countries. Hosted by the Inter-American Institute for Cooperation on Agriculture (IICA), the event offered participants a forum to jointly analyze and discuss the processes they are using to design, implement, monitor and evaluate their agricultural mitigation and adaptation plans and the lessons they have learned along the way.

Key challenges identified by the group include improving capacities to use science-based information and modeling tools to inform their planning processes, channeling sufficient domestic and international resources to enable implementation, and developing effective monitoring and evaluation systems to not only track progress but also to measure the impact of the efforts undertaken thus far.

The event was part of a broader strategic initiative led by IICA to develop capacity and facilitate integration of climate change mitigation and adaptation within agricultural planning in Latin America and the Caribbean.

Colombia has fostered a progressive and rigorous national dialogue about how each sector of the economy can contribute to the country's Low Carbon Development Strategy. As a result, Colombia has developed its **Nationally Appropriate Mitigation Action (NAMA)** within the **United Nations Framework Convention on Climate Change (UNFCCC)**. NAMAs are action plans that are measurable, reportable and verifiable and are established by national governments to deliver sustainable development to specific beneficiaries and sectors. NAMAs serve as investment vehicles to attract finance from donor governments and institutions in support of climate change mitigation programs.

Colombia's NAMA plan provides investment opportunities across many sectors, including agriculture and forestry, and features implementation and expansion of silvopastoral systems and eco-efficient practices in conventional pasture systems.

Policies to Improve Productivity and Sustainability in Colombia

Colombia has made profound transformations in its economic, political and social fabric over the past decade. The government is pursuing and implementing a good-governance agenda to strengthen institutions and democracy, and to move into a post-conflict era that brings inclusive growth to a wider number of people.

But high levels of income inequality persist, particularly between prosperous urban areas and remote, under-developed rural areas. Since agriculture is such a strong contributor to the rural economy, investments and policies to improve agricultural productivity and incomes will be a first step in boosting regional equity and in conserving Colombia's vital natural resource base.

Invest in Public R&D and Extension[10]

Colombia's Caribbean region and parts of its Andean region are projected to shift from a semi-humid to a semi-arid climate over the next century, requiring increased commitments to more R&D and extension to help farmers adapt to these challenges and conserve soil, water and biodiversity.

Small and medium-scale ranchers would benefit greatly from public agricultural research for better livestock breeding and genetics that are appropriate for conditions in their respective regions. Government extension services and cattle producer associations can play a vital role in helping these ranchers use best practices to improve animal health and productivity, and to become more competitive.

Colombia's main agricultural R&D agency, **Colombian Corporation of Agricultural Research (Corpoica)**, has benefited from a renewed level of support since the launch of Colombia's **National Research Development and Innovation Agenda** in 2011.

Corpoica conducts research across all regions of Colombia focusing on a wide range of crops, fruits and vegetables and livestock. Between 2006 and 2013, total agricultural research spending increased 33 percent, from $194 million to $254 million (in purchasing power parity dollars, constant 2011 prices). Spending as a share of agricultural gross domestic product (AgGDP) increased from 0.62 percent to 0.79 percent over this same period, but was still below the recommendation to spend at least one percent of AgGDP, a globally-recognized measure of research intensity. Annual budget increases are expected in the coming decades as the nation begins to prioritize its agriculture, research and extension investments.

Embrace Science-Based and Information Technologies[11]

Colombia has embraced science-based and information technologies while taking steps to reform its regulatory systems and to protect intellectual property rights (IP). This has helped attract domestic and international research and technology investments. Legal frameworks for IP are well developed, but enforcement is weaker, and Colombia must prioritize it going forward.

Colombia has made progress in attracting investment for information and communications technology (ICT), improving its telecommunications regulatory framework and promoting an internet economy. The ***Plan Vive Digital 2014–2018*** includes promotion and investment in ICT entrepreneurship as a priority. It is important that the Plan improves coverage for rural areas, where high-speed broadband coverage is weak and where agricultural producers need such technologies for extension and training services as well as to receive real-time information about weather and markets.

Enhance Private-Sector Involvement in Agriculture and Infrastructure Development[12]

As more than 40 percent of land ownership in Colombia remains informal, the land tenure system and formalization of land rights are foundational to improving agriculture and attracting investment, as well as providing farmers with collateral to access credit. Peace negotiations have brought land reform to the forefront of the agenda

A livestock forages nursery in Colombia's southwestern Cauca Department. Photo credit: Neil Palmer (CIAT)

and Colombia's budget has increased to support the government priority for improved land access, tenure and titling.

Infrastructure investments are key public goods required to link rural producers with urban markets. Colombia's internal freight transport costs rank among the highest in the world and rail and river transport represent only 15 percent and 5 percent of the freight market, respectively. Tertiary roads in Colombia are neglected and are in poor condition, hampering the ability of farmers to send products to value-chain buyers and increasing costs and spoilage. Colombia must explore innovative financing from sources such as private banks, pension funds and private equity for rural infrastructure development.

Cultivate Partnerships for Sustainable Agriculture and Improved Nutrition

According to the **Global Food Security Index**, Colombia has a relatively low proportion of the population undernourished (8.8 percent) and has steadily improved its food availability, quality and food safety over the past decade.[13] But for more than half of the rural population, and especially for those internally displaced by the civil war, poverty and poor nutrition are still major challenges requiring sustained investment and additional assistance to reduce their numbers. International development partnerships such as those with the **United Nations World Food Program** are helping internally displaced persons reintegrate after the end of the civil conflict by using innovative tools such as cash-based transfers and local purchases through farmers associations.

Public-private partnerships and commercial sources of funding are available in Colombia to help finance the establishment of sustainable agriculture and livestock systems. These include loan financing from **FINAGRO** (a public-private financial intermediary established in 1991 to provide low-cost financial products to Colombia's agricultural sector) and a **General Royalties System (Sistema General de Regalias, GRS)**, in which royalties from the extraction of non-renewable resources like oil, gas and minerals are provided to a range of social and economic development programs throughout the country.

Foster Capacity for Regional and Global Agricultural Trade

To take advantage of export opportunities for its agricultural sector, Colombia has entered into free trade agreements with Canada, the European Union and the United States. Colombia also has free trade agreements with Chile and countries throughout Latin America and is a party to the regional **MERCOSUR-Andean Community Agreement**. Colombia has increased its exports of commodities such as cacao, coffee and tropical fruit, but its beef producers must now begin to compete with imports from high-quality, low-cost exporters.

To improve the country's capacity to compete, Colombia has participated in various "aid for trade" trade-facilitation programs, such as those funded by the **Inter-American Development Bank (IDB)**. Support is provided to assist the Colombian Trade Ministry to deal more effectively with sanitary and phytosanitary (SPS) issues so that Colombia can export agricultural products more efficiently. The IDB **Aid for Trade Fund (AfT Fund)** helps Colombia and other developing countries integrate into the global economy and benefit from liberalized trade and increased market access by enhancing trade capacity.

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Kenyan farmer Syprose Aruma Apado uses high quality brachiaria forage grass for her dairy cows. Photo credit: CIAT

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