Productivity and Innovation: Sustainable Agricultural Growth in an Uncertain Season

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

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

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

Productivity itself is not simply producing more food, or even achieving higher yields. Productivity growth — a measure of output per unit of input — allows more to be produced while maximizing the use and impact of scarce resources. Productivity growth in agriculture lowers the cost per unit of output, helping producers succeed in today’s competitive business cycle, and enables agri-food systems to provide foods for consumers at lower prices.

Total Factor Productivity: A Measure of Innovation Adoption

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

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

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

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

WHAT IS SUSTAINABILITY IN AGRICULTURE?

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

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

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

TFP (Figure 2) is the ratio of agricultural outputs (gross crop and livestock output) to inputs (land, labor, fertilizer, feed, machinery and livestock). TFP measures changes in the efficiency with which all inputs are transformed into outputs. Producers, governments and agribusinesses who pursue this course are not just interested in whether agricultural output is growing, but to what extent increased output is due to better use of existing resources through the application of improved products, technologies and practices — essentially, how innovative their operations are. Examining Total Factor Productivity (TFP) is the best way to get that information, which can be enormously useful in identifying where improvements are needed in agricultural production systems, how to make investment decisions and what policies support more productive and sustainable agriculture.

### Productivity and Innovation in Practice

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

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

Ensuring that farmers and producers of all scales and sizes gain access to better innovation technology and training and knowledge for best practices will help foster greater TFP and reduce impact on the soil, water and air quality, as well as effectively use increasingly scarce labor in agricultural operations.
Placing productivity growth as a central policy goal can accelerate economic growth and raise incomes. As productivity growth increases, it allows laborers to produce more with less time, freeing up both labor and capital investments to move into other industries to produce more or different goods and services.

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

In the 1980s, thanks to the collaborative work of national agricultural research systems (NARs), private sector agriculture businesses, and global institutions such as the CGIAR (Consultative Group on International Agricultural Research), continuing improvements and refinements in agricultural technology began a more sustainable trajectory for agriculture production. Livestock and crop genetic advancements, better nutrition and feed for animals, improved machinery and farm equipment, and more efficient water use technologies — led by private sector research investments and innovation — are now accelerating productivity, as measured by TFP\(^2\) (Figure 3).

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

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

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**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

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

![Graph showing the sources of growth in global agricultural output from 1961 to 2013.](source: USDA Economic Research Service (2016).)
(fertilizer, machinery, feed, labor and crop protection) to output growth reduced dramatically. **On average, efficiency and innovation are beginning to account for a greater proportion of agricultural output worldwide.**

**TFP Variation by Income**

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

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

Raising productivity in low-income countries under the TFP approach will require increasing and sustaining investments in agricultural research and development (R&D), more effective knowledge transfer, training and extension services, expansion of rural infrastructure and access to finance for farmers, and value chain development. Low-income countries must place agriculture at the center of their policy agendas, incorporating climate-smart and resilient approaches and reforming policies to encourage adoption of innovation.

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

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

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

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

The GAP Index

In 2010, GHI calculated that global agricultural productivity (TFP) must grow by an average rate of at least 1.75 percent annually in order to double agricultural output through productivity gains by 2050. While output of food, feed, fiber and fuel will most likely continue to rise in coming decades to meet the growing global demand, experts are concerned that this production will come at the expense of the environment and natural resource base. In addition, agriculture production of livestock and crops contributes to greenhouse gas (GHG) emissions, further accelerating climate change.

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

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

The impact of this productivity gap for low-income, food-deficit countries (where population growth is rapidly rising) will place strains on the resource base and may lead to more food price spikes as these countries lack the income to import enough food to meet the needs of their citizens. Poor urban households will bear the brunt of higher food prices in these countries, but they will also impact rural populations, since they are net food buyers.
Spotlight on Regional Productivity Gaps

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

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

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

Note on methodology: The projection of agricultural output from TFP growth uses USDA ERS (2016) estimates of average TFP growth during 2004–2013 and assumes this is maintained through 2030. The projected growth in food demand uses UN estimates of population, PricewaterhouseCoopers LLP (PwC) estimates of GDP growth, and estimates of the income elasticity of food demand from Tweeten and Thompson (2008). The income elasticity of food demand indicates the share of the growth in per capita income that will be spent on food. Multiplying the income elasticity by the growth rate in per capita income gives the growth rate in per capita food consumption holding food prices fixed. Adding this to the population growth gives the total growth in food demand for a given price level.