COLLEGE OF AGRICULTURE AND LIFE SCIENCES
VIRGINIA TECH

GAP REPORT®
GLOBAL AGRICULTURAL PRODUCTIVITY REPORT®

every FARMER every TOOL

2023 GAP Report®

Executive Summary

ABSTRACT

Agricultural total factor productivity (TFP) growth has the potential to create returns to farmers–at all scales of production, society, the environment, and the economy. However, since 2011, average annual TFP growth has consistently fallen below the target growth rate required to sustainably meet global needs for agricultural outputs by 2050. Now, we must redouble our efforts to sustainably grow TFP. While research and development (R&D) is a key driver of TFP growth, there are many existing proven tools for sustainably improving TFP. In addition, the wider enabling environment, influences of behavior and decision-making, and external shocks and forces influence access to and sustained adoption of these proven tools. From research to stories from the field, the 2023 GAP Report® explores the opportunities and barriers to farmer access and adoption of proven, appropriate tools for sustainable agricultural productivity growth.

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FOREWORD

The United States of America and, indeed, the entire food and agriculture sector is blessed to have a wealth of data and analytics at its disposal to address the many and growing challenges of our world. From our first-rate universities, think tanks, governments, and other sources emerges one seminal report that stands out in its global importance–the Global Agricultural Productivity (GAP) Report.

Agriculture has become so very diverse in its cropping, animals, geographies, technologies, inputs, markets, weather, and even politics. It could be easy to lose sight of the most critical goal on which societies around the world should be focused.

I assert that feeding almost 10 billion persons by 2050 is and must be our primary focus, a point from which we cannot stray. Indeed, the first two goals of the United Nations Sustainable Development Goals reflect this. However, the threats of climate change, war and strife, technology innovation (and rejection), economic fluctuation, and other mega-factors oftentimes obscure that which is most important. In fact, some countries around the world are foregoing *agricultural productivity* growth as they focus solely on their quest to solve *other problems*.

A good example of this is the problem of climate change, which is very important and must be front-and-center but often becomes the singular focus of policymakers. While understandable, our goal should and *must* be to address both climatic variability and agricultural productivity.

At the National Association of State Departments of Agriculture, we advocate for the power of “AND,” which marries the GAP Report’s Total Factor Productivity analysis, the efficiency with which we produce our crops, animals, and aquatics, with the additional focus on addressing problems facing the food and agriculture industry. The power of “AND” allows farmers to sustainably pursue our primary goal–the production of food to address hunger and nutrition needs of communities around the world.

NASDA encourages all involved with food and agriculture globally to embrace this report, share it, and certainly to adopt its recommendations such that our world will be fed adequately in 2050.

Ted McKinney
CEO
National Association of State Departments of Agriculture (NASDA)

KEY MESSAGES

1. Increasingly at the forefront of global policy dialogues, sustainable productivity growth is recognized as the single most effective solution to meeting demand for agricultural output and meeting environmental goals.

2. Total factor productivity (TFP) growth continues to be strong in China and South Asia, but is well below target growth across most of the globe. Sub-Saharan Africa and the United States show especially low TFP growth.

3. During 2011-2021, global TFP grew at an average of just 1.14 percent annually. To sustainably meet the agricultural needs of a growing global population by 2050, we must now aim for 1.91 percent average annual TFP growth.

4. If producers at all scales of production are able to access proven, appropriate, productivity-enhancing tools, including technologies and practices, we can make significant strides in closing the TFP growth gap. Increasing access to and adoption of proven-productivity enhancing tools will require strengthening the enabling environment, addressing influences of food system actor behaviors, and mitigating the effects of external shocks and forces.

5. Lack of TFP growth creates reliance on input intensification and land expansion to grow agricultural output. This may result in over-reliance on unsustainable production practices and continued decline in TFP growth.

6. Collaboration between the public, private, and civil sectors is critical for tackling barriers to every farmer having access to every proven tool for sustainable agricultural productivity growth.

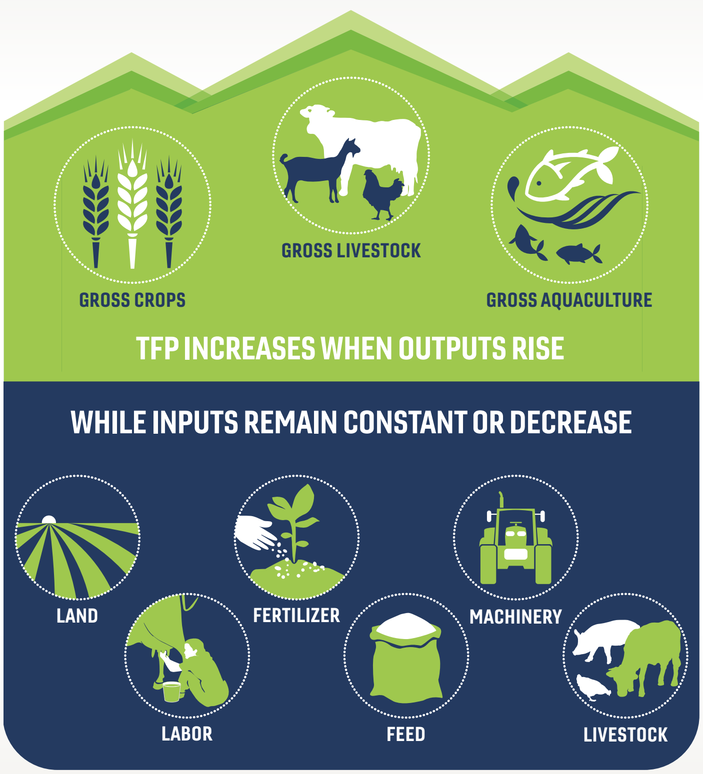
TOTAL FACTOR PRODUCTIVITY: UNCOVERING THE SUSTAINABILITY OF AGRICULTURAL SYSTEMS

There is mounting pressure to find solutions to short- and long-term challenges facing local, regional, and global food systems. Major shocks, climatic variability, and rapidly changing demand for agricultural products have revealed fragile foundations and the need for a new *modus operandi* in the way food and other agricultural outputs are produced.

Agricultural productivity growth is and will continue to be at the core of strengthening sustainable agricultural systems. Indeed, improved efficiency of input and natural resource use has been increasingly emphasized as the single most effective solution to simultaneously achieving production and environmental goals (Searchinger et al., 2019).

Measured as total factor productivity (TFP), agricultural productivity growth is achieved when producers increase their output of crops, livestock, or aquaculture products, using the same amount or less land, labor, capital, fertilizer, feed, and livestock. In other words, TFP rises when producers utilize innovative agricultural technologies or labor and efficiency practices to increase output with the same amount or fewer resources (Figure 1).

Figure 1: Total Factor Productivity



Tracking changes in TFP growth reveals a bigger picture of how well agricultural production is able to contribute to pressing global issues such as poverty alleviation, food security and nutrition improvements, and environmental externality reduction (Rahman et al., 2022). For example, TFP growth can lead to increased competitiveness in the sector through lower production costs. A one percent increase in productivity growth is equivalent to a one percent decrease in the cost of producing, storing, and selling one unit of a particular product. Consumers also benefit from TFP growth since the per-unit price for producers moves through the value chain, influencing the prices consumers pay.

Changes in TFP also reveal how well our agricultural knowledge and innovation systems (AKIS) are reaching and supporting producers at all scales of production to improve productivity. An increase in TFP growth suggests that an increasing number of producers are adopting, at minimum, scientifically proven, contextually- and scale-appropriate tools–such as technologies, strategies, and practices–that improve the sustainable use of scarce resources, including non-renewables.

When the GAP Report® was first published in 2010, the "GAP Index" was established to track changes in TFP growth and to illustrate the future growth necessary–holding inputs constant–to sustainably fulfill global needs for agricultural products by 2050. The GAP Index target, which was a projected rate of 1.73 percent average annual TFP growth during 2010-2050 (solid green line, Figure 2), was based on the assumption that agricultural outputs would need to double between 2010 and 2050 to support a projected population of 10 billion people.

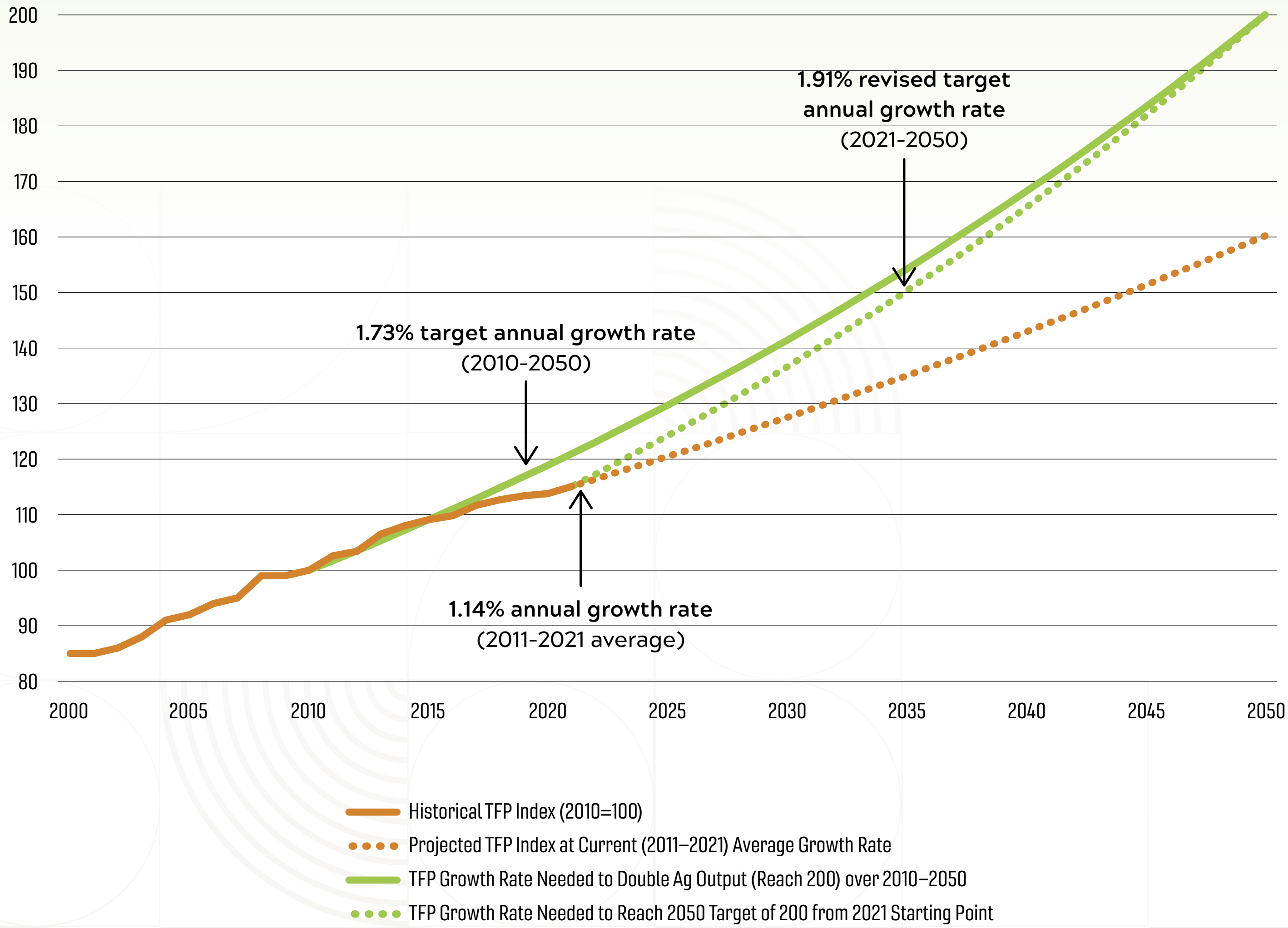
In 2022, the United Nations estimated that the global population could reach 9.7 billion by 2050 (United Nations, 2022). Although this estimate is slightly lower than earlier projections, we conclude that the assumption of needing to double agricultural production from 2010 to 2050 is still valid, especially because this assumption does not explicitly account for any negative impacts of climate change–which will continue to have important impacts on agricultural production and outputs.

At 1.14 percent, the global average annual TFP growth during 2011-2021 (orange line, Figure 2) fell well below the 1.73 percent annual growth GAP Index target. As a result of sluggish TFP growth during this period, it is now necessary to revise the GAP Index target upward to 1.91 percent average annual growth (dotted green line, Figure 2) to achieve sustainable production of global agricultural needs by 2050. If TFP growth continues to lag, the gap will continue to widen over time, making it increasingly difficult to close.

Figure 2:

2023 GLOBAL AGRICULTURAL PRODUCTIVITY INDEX

TFP growth rates are based on a 10-year rolling average



Source: USDA Economic Research Service (2023).

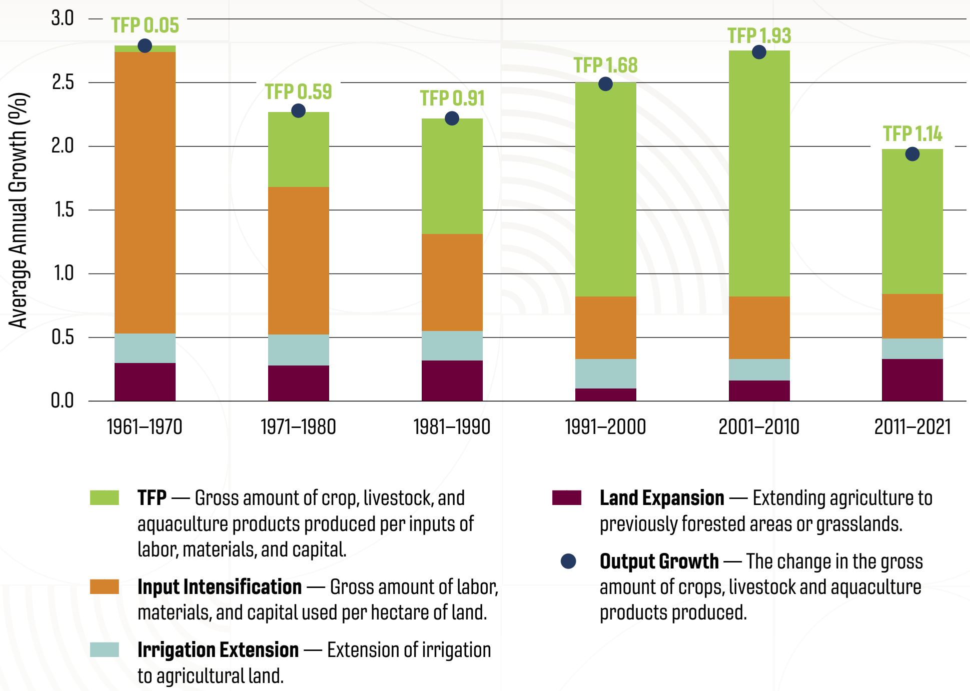
The implications of a widening TFP growth gap include the use of unsustainable agricultural practices, such as the conversion of wild and marginal lands to agricultural production. As a result of such practices, a portion of the gap will remain unfilled, leading to unacceptably high levels of malnutrition and rural poverty, accelerated loss of biodiversity, and detrimental system-wide inefficiencies. This gap will disproportionately impact already resource-poor communities.

Input intensification, such as the adoption of improved crop varieties, increased application of fertilizers and crop protection products, and use of mechanization, was the most important driver of increased agricultural output during the 1960s and 1970s (Figure 3). However, beginning in the 1980s, TFP growth became the leading contributor to agricultural output growth until the present day. During the 1990s, global TFP growth averaged 1.68 percent annually, which increased to 1.93 percent average annual TFP growth during the first decade of the 21st century. Unfortunately, during 2011-2021, average annual global TFP growth fell to 1.14 percent, ending two decades of robust growth and falling well below the global GAP Index target (Figure 2).

TFP growth declined sharply during 2011-2021, compared with 2001-2010, across all country income groups. Global TFP growth was a robust 1.93 percent annually during 2001-2010, but declined by an average 43 percent during the subsequent decade (Figure 4). The robust TFP growth of middle-income countries also declined sharply and was below the new target growth rate (1.91 percent annually) during 2011-2021. TFP growth in upper-middle-income countries declined by more than 50 percent between 2001-2010 and 2011-2021.

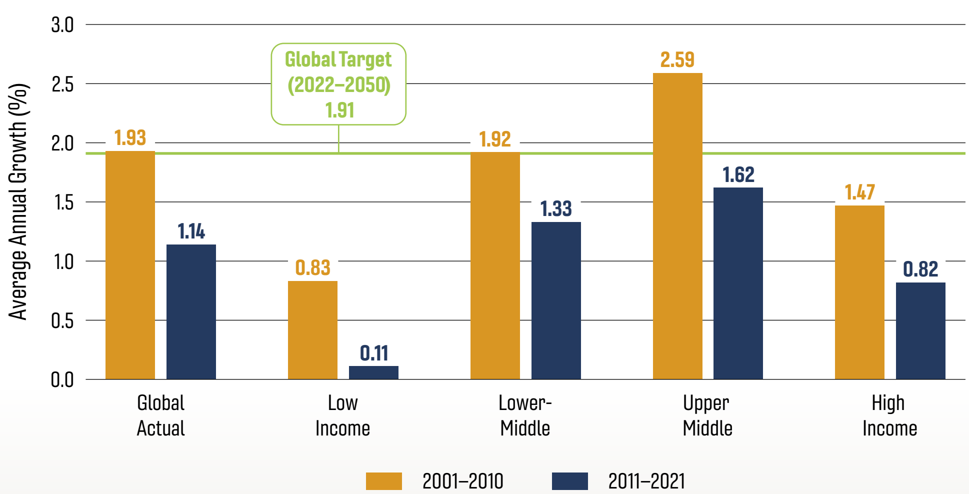
Low-income country TFP growth continues to lag, as reported in the 2022 GAP Report (Steensland, 2022). Low TFP growth suggests that both the pace of innovation and the adoption of agricultural innovations are declining. This trend is especially alarming, considering the agricultural production challenges of

Figure 3: Global Sources of Agricultural Output Growth, 1961–2021



Source: USDA Economic Research Service (2023).

Figure 4: TFP Growth by Country Income Group, 2001–2021



Source: USDA Economic Research Service (2023).

the coming years. This contraction in TFP growth may exacerbate already high levels of food insecurity and malnutrition and threaten the prospects for agriculture-led economic growth in many nations.

During 2011-2021, South Asia and China were the only world regions that experienced strong TFP growth (Figure 5). Strong TFP growth in South Asia (2.18 percent) was led by India and Pakistan (2.47 and 2.41 percent, respectively). Within the South Asia region, only Bangladesh (-1.16 percent annually) suffered from TFP contraction. Increasing productivity in South Asia has been linked mostly to technological change, including technology adoption, mechanization, labor reallocation, and adoption of information and communications technology (ICT) to disseminate information related to agriculture (Liu et al., 2020a).

TFP growth in China (1.97 percent) has been driven by mechanization (Liu et al., 2020b) and policies aimed at reversing unsustainable input intensification practices (OECD, 2018). Chinese government investments in agricultural research and development have no doubt played a role as well–China now spends more than twice as much on public agricultural research and development as the United States (Plastina and Townsend, 2023).

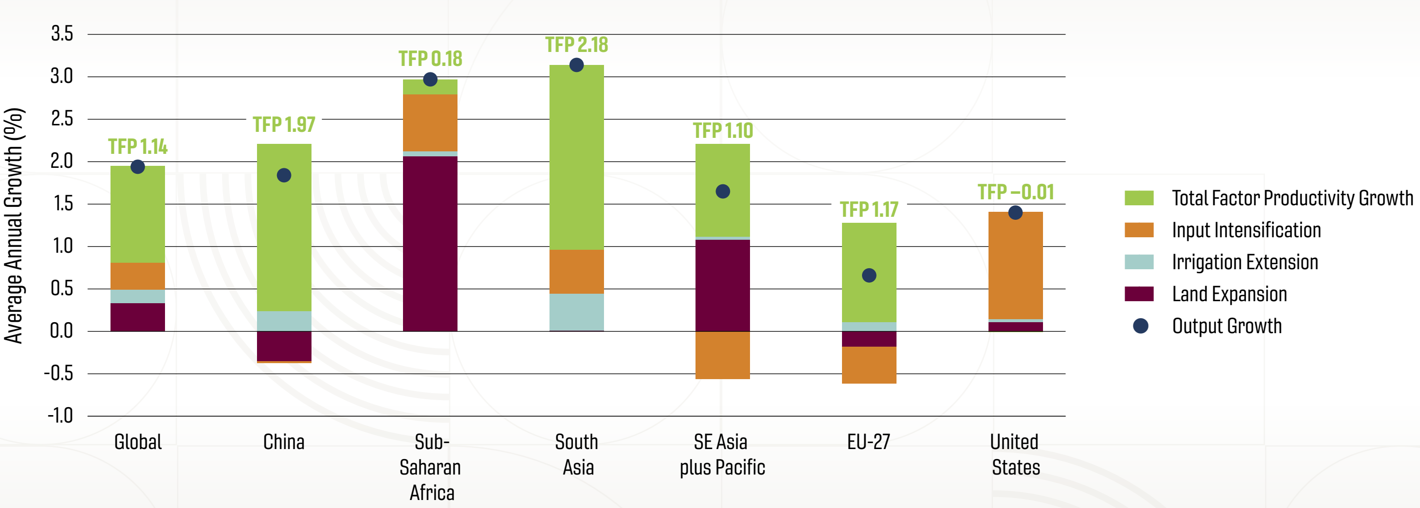
In the Southeast Asia and Pacific region TFP growth averaged 3.0 percent annually during 2001-2010, but fell sharply to only 1.1 percent annually during 2011-2021. Land conversion to agriculture, led by Indonesia and Laos, was the largest contributor to agricultural output growth in the region.

In sub-Saharan Africa (SSA), lagging TFP growth can be attributed to various factors, including lack of technological change, low expenditures on agricultural research and development, and climate change impacts, which appear to be most severe in warm regions (Ortiz-Bobea et al., 2021). With constrained access to productivity-enhancing tools such as mechanization, advanced seeds, fertilizer, and improved livestock breeds and feed, farmers are expanding agricultural land into wildlands at an alarming rate, with negative impacts on biodiversity (Koch et al., 2019).

In SSA, the conversion of lands to agricultural production (Figure 5) was the highest seen since the 1980s and average TFP growth (0.18 percent annually) was the lowest observed since the 1970s. Eight countries in SSA increased agricultural land area (cropland plus permanent pasture) by more than 3 percent annually during 2011-2021, and more than 100,000,000 hectares of land were converted to agricultural use across SSA during this period. Of the major SSA sub-regions, only the Sahel and Southern Africa experienced positive (0.88 and 0.72 percent annually) average TFP growth during 2011-2021. In sharp contrast, average TFP growth was -1.54 percent annually in East Africa.

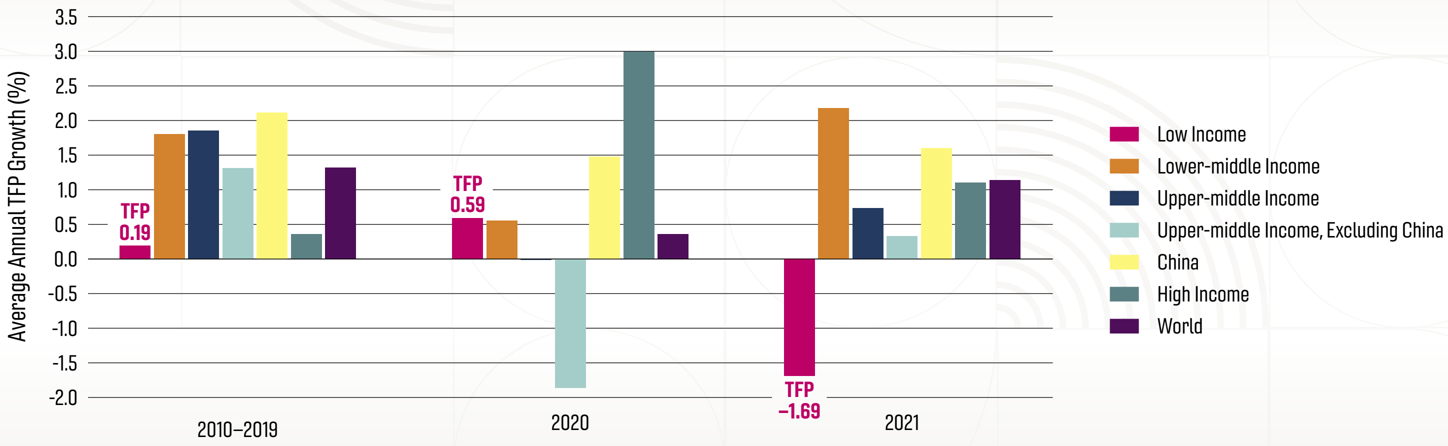
Average TFP growth in the United States has dropped markedly from 1.49 percent annually during the 1990s, 1.39 percent annually during 2001-2010, to negative during 2011-2021 (Figure 5). It is noteworthy that, according to USDA-ERS, in

Figure 5: Sources of Agricultural Output Growth By Region, 2011–2021



Source: USDA Economic Research Service (2023).

Figure 6: Short-Term TFP Growth



Source: USDA Economic Research Service (2023).

2019, U.S. public agriculture and food R&D expenditures in constant dollars reached its lowest level since 1970 (Nelson and Fuglie, 2022).

It may take several more years to understand the full impacts of the COVID-19 pandemic on agricultural productivity. For example, government actions in response to the pandemic inhibited the normal flow of agricultural production, marketing, and access to inputs, which increased the number of individuals suffering from food insecurity (FAO, 2021). With the updated global TFP data now available from USDA-ERS, we have the opportunity to examine the short-term (up to 18 months) impacts of the COVID-19 pandemic on TFP growth.

Most country-income groups experienced lower TFP growth in 2020 compared to 2010-2019, except for low-income and high-income countries, which experienced higher TFP growth (Figure 6). This contributed to a very low global average TFP growth of 0.5 percent in 2020. In the GAP Report, we usually do not report on annual variations in TFP, so as to emphasize longer-term trends in TFP growth, which are largely driven by technological change. Nevertheless, the large decrease in TFP growth in 2021 in low-income countries (-1.69 percent annual loss) should be of concern, especially because it comes on the heels of a decade of no growth in agricultural TFP.

Global growth in the production of agricultural products continues to exceed population growth, as it has every year since 1994 (except for 2009). Average annual global population growth during 2011-2021 was 1.11 percent (Ritchie et al., 2023). During the same period, the annual output of agricultural products grew by 1.94 percent annually.

However, global demand for agricultural outputs is still not being met as a result of system failures such as distribution inefficiencies, food loss and waste, and socio-economic inequalities. As a result, undernourishment continues to be an acute problem, with more than 800 million people still facing chronic hunger globally. In 2021, the FAO estimated that the prevalence of undernourishment jumped from 8.4 to 9.9 percent of the global population in just one year (FAO et al., 2021). Inciting events, such as the COVID-19 pandemic and the Russian invasion of Ukraine, which restricted the movement of food and resources in both the short- and long-term, have and will continue to exacerbate this number.

In light of our current food environment, we face a dual imperative–to sustainably improve agricultural productivity at all scales of production in local, regional, and global food systems while simultaneously ensuring that TFP growth creates returns for the producer, society, the environment, and the economy. There are already numerous technologies, practices, and strategies that have proven successful in achieving this dual goal. Ensuring that every farmer has access to every proven and appropriate productivity-enhancing tool could significantly contribute to closing the productivity gap.

REGIONAL SPOTLIGHT: UNVEILING AGRICULTURAL PRODUCTIVITY TRENDS IN LATIN AMERICA AND THE CARIBBEAN

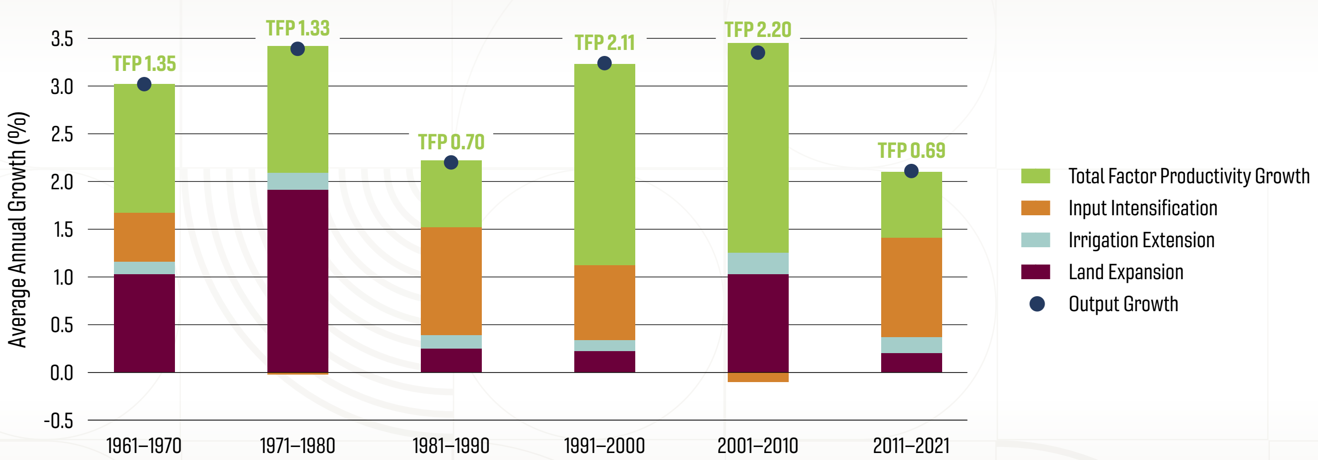
Latin America and the Caribbean (LAC) is one of the largest net food exporters globally, and, in the decade up until 2015, was an outperforming region in terms of poverty and malnutrition reduction (FAO, 2023). Major climatic and economic disruptions have presented LAC agri-food systems with challenges, such as rising input prices, constrained ability to participate in global markets, and crop devastation resulting from droughts (Piñeiro et al., 2020; Wilson Center, 2022). This has resulted in an increasing number of people who are unable to afford a nutritious diet and growing sustainability concerns. However, increased investment in scientific research and innovation, especially in precision agriculture, more robust policy frameworks for sustainable and productive food systems, and inter-sectoral cooperation, can reposition the LAC region at the forefront of regional and global agricultural needs for improved livelihoods and environmental sustainability (FAO, 2023; CGIAR, 2023).

SOURCES OF LAC AGRICULTURAL OUTPUT GROWTH SINCE 1960

During the 1960s and 1970s, land newly converted to agricultural production was the major driver of agricultural output growth in the LAC region; however, average TFP growth was the second largest contributor during this period (Figure 7). Land expansion and TFP growth tapered off during the following decade, and intensification of input use was the largest contributor to output growth. During the 1990s and 2000s, TFP growth was robust in the LAC region, led by technological change that contributed the most to output growth. However, during 2011-2021, average TFP growth in the region decreased to only 0.69 percent annually, an almost 70 percent decline compared to the previous decade (2001-2010). Currently, in LAC, producers are once again relying primarily on input intensification to increase output, applying more inputs, such as labor, fertilizer, and capital, per hectare of land (Figure 7). Agricultural output growth in LAC also decreased significantly during 2011-2021 compared to 2001-2010, to its lowest decadal value since before 1961.

LAC regions with strong TFP growth during 2001-2010 suffered serious growth declines during 2011-2021, including Central America, where average TFP growth declined from 1.6 percent annually during 2001-2010 to 1.0 percent annually

Figure 7: Sources of Agricultural Output Growth in LAC, 1961–2021



Source: USDA Economic Research Service (2023).

during 2011-2021. Similar declines occurred in Andean countries (Bolivia, Columbia, Ecuador, Peru), where average TFP growth fell from 2.0 percent annually to 0.79 percent. Brazil experienced a strong 3.8 percent annual average TFP growth during 2001-2010, but this growth fell sharply to 1.53 percent annually during 2011-2021 (Figure 8).

Input intensification also grew sharply from 2001-2010 to 2011-2021 in Central America, Andean countries, and Southern Cone countries (Argentina, Chile, Paraguay, Uruguay). For example, during 2011-2021, fertilizer consumption increased by almost 4.0 percent annually across Central American countries. Input intensification (an average of 2.46 percent annual increase) was especially important in Mexico as a means of increasing output. During 2011-2021, for example, fertilizer and livestock feed use by Mexican producers increased annually by an average 2.2 and 3.4 percent, respectively.

In sharp contrast to Brazil and Mexico, Haiti suffered from shrinking TFP and a 2.5 percent loss of agricultural output during 2011-2021. Serious and ongoing civil and political unrest, resulting in the abandonment of agricultural land, extreme weather events such as droughts and floods, and little to no infrastructure for irrigation or transportation have contributed to a troubling state of the Haitian agricultural sector, detrimentally affecting its predominantly agrarian population.

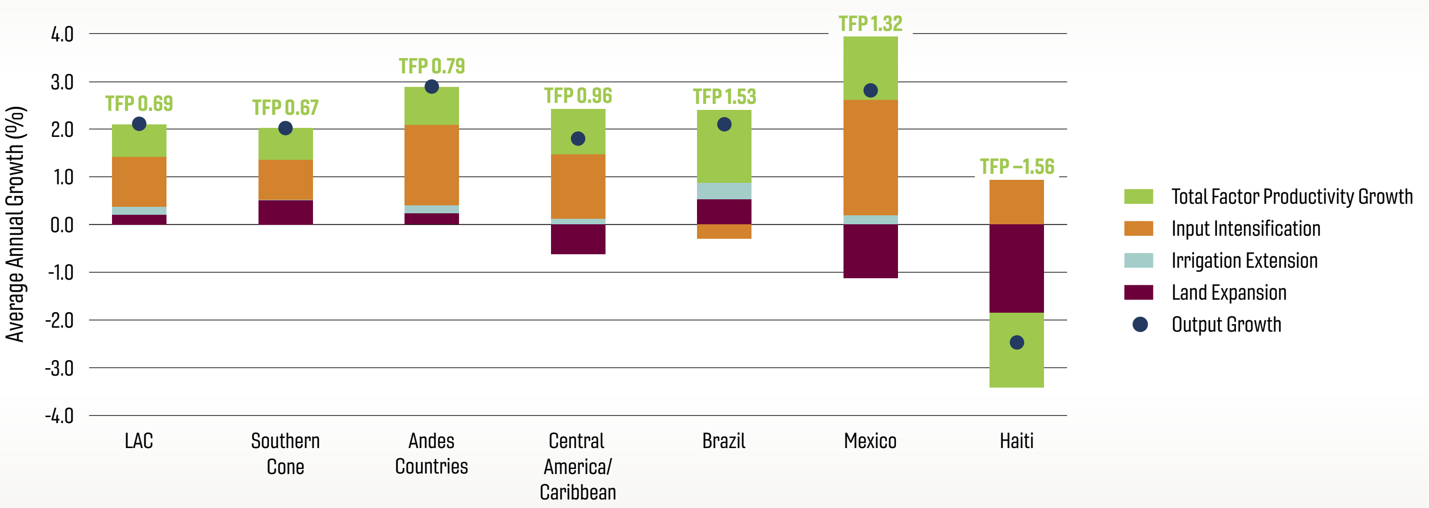
The LAC region, and indeed the world, benefitted from strong TFP growth during the decades of the 1990s and 2000s. The sharp decrease in TFP growth from 2011-2021 emphasizes the need for commitment to strengthen the enabling environment for productivity-enhancing tools, reduce barriers to adopting those tools, and find opportunities to reduce the impact of external shocks and forces to make innovations available to producers at all scales of agriculture.

LAC'S ENABLING ENVIRONMENT INVESTMENTS

New policy initiatives and investments in LAC are focused on improving agricultural productivity to address the rising costs of a nutritious diet and stagnating poverty reduction, while protecting the region's vast natural capital and biodiversity.

Take, for example, **Panama**'s recent *State Agrifood Policy Act*, which aims to increase access to healthy and nutritious food at affordable prices. The law establishes four areas of structural reforms: agrotechnology use and production value chains; agri-food education; public sector legal framework and management model; and a welfare model for rural families. It aims to create conditions for the technological transformation of agriculture and establishes guidelines related to productivity, competitiveness, food sovereignty,

Figure 8: Sources of Agricultural Output Growth in LAC, Regions and Selected Countries, 2011–2021



Source: USDA Economic Research Service (2023).

and legal security (IICA, 2023a). Its launch catalyzed a portfolio of investment projects, valued at $1.2 billion over the next ten years, focused on technological transformation of agriculture, especially emphasizing the inclusion of youth, rural women, and family farmers. “Protected Horticulture” is one such project, which will aim to improve family horticultural operations using controlled environment agriculture, such as greenhouses and indoor farming operations, through technological innovations that reduce applications of pesticides.

One of the Act’s priorities is taking into account the voices of commercial producers, consumers, importers, traders, family farmers, and indigenous peoples in developing its projects (IICA, 2023b). This inclusion of Panamanian voices, including incorporating the input of family farmers in the “Protected Horticulture” project, is vital for developing policy that is relevant, tailored, and sustainable over the long-term.

In **Panama** and other tropical nations, there has been under-development of adequate technologies for crop production, which has resulted in the importation of foreign tools (Collado et al., 2018)–but the introduction of innovative tools alone does not equal agricultural productivity growth. Amid the backdrop of the *State Agrifood Policy Act*, the development of locally-sourced crop protection tools aimed at increasing food security, coupled with robust business models that are inclusive of the specific needs of farming communities, is hoped to increase sustained adoption and success of these tools.

Horticultural production is a growing and increasingly competitive market, especially for Central America and the Caribbean (OECD & FAO, 2019). In the **Dominican Republic** (DR), the Ministry of Higher Education, Science, and Technology is collaborating with the Specialized Institute of Higher Studies Loyola and faculty from Virginia Tech to research water use for avocado farming and identify potential applications of remote sensing technologies for the estimation of water needs. The country produces 5.7 million tons of avocados every year; however, since 2019, multiple reports have described increased avocado plantings within natural reservation areas, established by low-income farmers with little to no access to farming land. One of the primary public concerns is the detrimental effects that deforestation and the planting of fruit crops could have on the aquifers and water sources of the country, ultimately impacting agricultural production overall.

Researchers from the collaborating teams assessed four irrigation treatments to better understand if the crops were over-irrigated, using drones to measure plant health from different physical ranges. Data from the study indicated that avocado farmers in the DR are significantly over-irrigating their avocados. Improving farmer knowledge of irrigation needs and access to advanced management tools will yield benefits for farmers and the nation. In order to increase the adoption of productivity-enhancing tools, it’s vital to make known to producers the returns for improving management practices, such as water cost savings in avocado production, by sharing the results of the research.

Enabling environments can more effectively facilitate the transfer of agricultural R&D and productivity-enhancing tools when the sector is more efficiently organized. In **Argentina**, for example, the establishment of farm organizational structures called “planting pools” has played a significant role in increasing agricultural productivity throughout the country. Planting pools are formal contracts between producers, investors, and other agricultural supply chain actors that are responsible for production processes, such as inputs, labor, and financing. Investors enter into rental contracts with landowners across regions to engage in production activities. These agreements are often overseen by professional agricultural consultants who manage production. Planting pools have been successful at attracting new financial capital into agriculture, incorporating improved production practices and technologies on the farm, and using mechanisms such as insurance to better organize agri-management.

The establishment of planting pools could lead to improved production practices and the use of more advanced technology among farmers. Data from an early agricultural census shows that those involved in planting pools are more likely to perform soil analysis and monitor pests, ultimately improving production in the long term (Lence, 2010). Increasing farmers’ access to non-traditional contracts and financing opportunities has the potential to de-risk business, which is especially meaningful for small-scale farmers who may not be as capable of taking early major financial steps on their own.

There is no single solution to alleviating the complex and ever-evolving impacts of an unpredictable climate, rising global population, and resource scarcity–or for introducing more effective tools to farmers. Nevertheless, context-relevant policy development, evidence-based research, and the expansion of agricultural financing are valuable pathways toward developing an enabling environment that not only fosters access to but also the long-term use of productivity-enhancing tools in Latin America.

ADVANCING AGRICULTURAL PRODUCTIVITY AND SUSTAINABILITY—TOGETHER

OPINION: **Andres Rodriguez, Agricultural Attaché, Embassy of Chile to the United States**

Sustainability and food security are two of the main strategic pillars of the Ministry of Agriculture of Chile. If we want to ensure food security, we must be more efficient and productive–in other words, produce more with less. If this goal is not already challenging enough, obstacles such as climate change, drought, and soil erosion pervade.

Chile is committed not only to food security but also to sustainability, and there's no other way than to take our creativity to its maximum expression–and let collaborative work take a key role.

One of the main collaborative initiatives between Chilean and U.S. scientific institutions is the NASA DEVELOP program. This year, we celebrate ten years of working together on this successful program. The first project with Chile was snowmelt modeling from the Andean snowpack for more effective water allocation and planning in the Atacama Region of Chile. In the most recent project, in partnership with CIREN (Natural Resources Information Center, under the Chilean Ministry of Agriculture), we worked on calculating specific crop coefficients in the Maipo River Valley using available Earth observations from space, allowing us to evaluate crop evapotranspiration and irrigation requirements without ground instruments. This would enable the potential to improve irrigation efficiency and reduce water consumption. These are great examples of how we can use water more productively.

Another important initiative is the "Systems Approach," a strategy to decrease greenhouse gas emissions in agriculture. After two decades of negotiations, Chile is in the last mile of the authorization process of the Systems Approach for table grape exports to the North American market.

This agreement will allow importers in the U.S. to receive table grapes without methyl bromide fumigation from low pest-prevalence areas in regions of Chile, such as Atacama, Coquimbo, and Valparaíso, that meet the demanding requirements established.

In those eligible areas, the application of methyl bromide will be replaced with different approaches that the Systems Approach considers, such as registration of growers who demonstrate their compliance, traps in orchards, field monitoring, and U.S.-Chile certificate of origin joint inspection to ensure the export of a safer, higher quality, greener product.

This initiative will not only help to reduce the environmental footprint of horticultural production and trade, but will also help to reduce post-harvest loss–a key contributor to improving agricultural productivity.

Let us embrace the spirit of collaboration and innovation as we work together towards food security and safeguarding our planet for future generations, working hand-in-hand to advance productivity and sustainability.

Read the full articles from Panama, the Dominican Republic, and Argentina

EVERY FARMER, EVERY TOOL: A FRAMEWORK FOR SUCCESS

Since the 1970s, agricultural innovation of technologies, practices, and strategies have contributed to more productive agricultural systems that are increasingly able to provide returns to producers, society, the environment, and the economy. However, the previous decade's (2011-2021) sluggish TFP growth suggests that, particularly in low-income countries, the adoption rate of proven productivity-enhancing tools is not sufficient to contribute to sustainable productivity growth. To reach the new annual target TFP growth rate of 1.91 percent and to reduce the need to increase agricultural output through unsustainable practices, we must seek to lessen the barriers that farmers at all scales of production face in accessing and adopting proven, appropriate productivity-enhancing tools.

PROVEN & EMERGING TOOLS FOR SUSTAINABLE TFP GROWTH

There are well-established tools–including technologies, practices, and strategies–that have demonstrated success in improving farm efficiency and sustainable productivity by optimizing resource utilization and minimizing environmental and economic costs. Ongoing R&D improves existing tools and identifies and validates new ones to sustainably improve productivity, farmer livelihoods, environmental and human health, and economic growth.

1. Improved Genetics

Improved crop and livestock genetics help to maximize yield and nutritional quality while increasing tolerance to various environmental stresses and minimizing input requirements.

a. Traditional and marker-assisted breeding
b. Transgenic technology
c. Gene editing
d. Assisted reproductive technologies
e. Selective breeding

2. Precision Agriculture

Data, technology, and automation are leveraged to make production management more precise and resource-efficient (Monteiro et al., 2021).

a. Low-flow (e.g. drip) irrigation
b. Information and communication technologies–geographic information systems (GIS), satellites, artificial intelligence and machine learning, and sensors
c. Drones and autonomous vehicles
d. Variable rate technology
e. Precision seeding and feeding

3. Soil Health Management

Healthy soil is integral to sustainable productivity. Soil health management practices reduce erosion, maximize water infiltration, improve nutrient cycling, reduce the need for inputs, and improve land resilience (USDA, 2023).

a. Regenerative practices–reduced or no-till, cover crops, rotational grazing, and crop rotation

b. Integrated nutrient management–fertilizers, crop residues, animal manures, and compost

c. Soil cover and living root presence

4. Integrated Production Systems

Local integration of production systems (cropping and livestock, aquaculture) increases agricultural output while strengthening ecosystem services and reducing the environmental impacts of resource use (Lemaire et al., 2014).

a. Integration of crop and livestock systems

b. Ecosystem integration, such as agroforestry

c. Controlled environment agriculture, such as aquaculture or hydroponics

5. Pest & Disease Management

Pests and disease are a major threat to producer productivity and input costs. Efficient and effective control of these threats while also maintaining ecosystem services is critical to sustainable productivity growth (USDA , n.d.).

a. Precision spraying and chemical control

b. Biological control–pest predators, semiochemicals, habitat provision for natural enemies

c. Integrated Pest Management–the combination of a variety of practices, including cultural practices (e.g., crop rotation, tillage, water management, crop protection)

6. Mechanization & Automation

Machinery and agricultural engineering maximizes labor productivity, improves output quality, minimizes loss, and maximizes resource utilization efficiency.

a. Drones, autonomous vehicles/robots, and sensors

b. Tractors, harvesters, and precision planters

c. Implements enabling reduced or minimum tillage.

7. Knowledge-sharing Platforms

Training on new and existing productivity-enhancing tools is necessary for optimizing the use of the tools, minimizing costs, and maximizing uptake. Knowledge sharing on how to incorporate new technologies into indigenous farming practices is critical for attaining productivity growth (Muthee et al., 2019).

a. Farmer field schools and technical and vocational education and training institutes

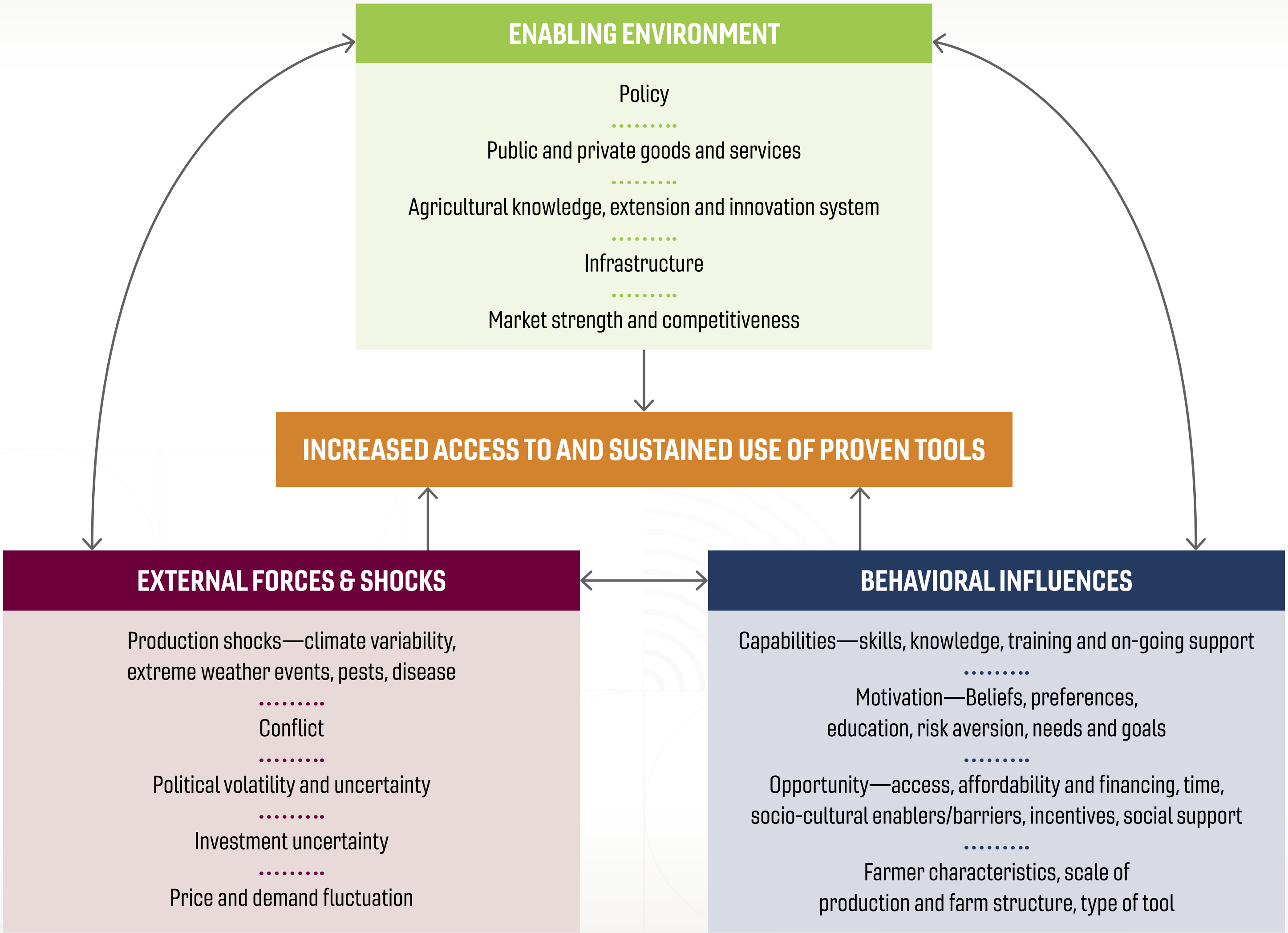
b. Extension and advisory services

c. Digital platforms and apps

INCREASING ACCESS AND ADOPTION OF PRODUCTIVITY-ENHANCING TOOLS

Producer access to and sustained adoption of productivity-enhancing tools is impacted by the wider enabling environment, behavioral influences, and external forces and shocks (Figure 9). Within each of these milieus, barriers and opportunities for tool uptake are reinforced by socio-economic contexts, production scale, and the agro-ecological environment. This framework can be used to identify policies and investments that will ensure every farmer has access to and can sustainably adopt every proven, appropriate productivity-enhancing tool.

Figure 9: Framework for Access and Adoption of Productivity-Enhancing Tools



Enabling Environment

Agricultural productivity growth is impacted by the multifaceted setting of the agricultural sector, food systems, and the wider economy. This enabling environment for tool access and adoption includes (1) policy (agricultural, macroeconomic, non-farm sectors), (2) public and private provision of goods and services, (3) the agricultural knowledge, extension, and innovation system, (4) infrastructure, and (5) market strength and competitiveness.

The enabling environment affects access to and adoption of sustainable productivity-enhancing tools by influencing the resources available for research and development the flow and dissemination of tools, incentives for technological adoption, magnitude and variability of returns on investment, uncertainty and risk, and long-term availability. Examples from across the world demonstrate how these elements work alone and in concert to foster enabling conditions or barriers to accessing and sustaining the adoption of proven, appropriate productivity-enhancing tools (Table 1). The enabling environment is largely dependent on political will, perceived economic growth opportunity, and available evidence to inform the efficacy of policy and practice, illustrated in the examples in Table 1.

Table 1: Examples of Enabling Environment Impacts on Tool Adoption

POLICY	PUBLIC & PRIVATE GOODS & SERVICES	AGRICULTURAL KNOWLEDGE, EXTENSION & INNOVATION SYSTEMS	INFRASTRUCTURE	MARKET STRENGTH & COMPETITIVENESS
Agricultural input subsidies and coupled payments have a negative relationship with TFP growth in the Organisation for Economic Co-operation and Development (OECD) countries (DeBoe, 2020).	Service-sharing platforms like Hello Tractor improve access to mechanization in sub-Saharan Africa.	The European Union supports agricultural knowledge and innovation systems (AKIS) to support developing and scaling innovations through co-creation and knowledge sharing between advisors, farmers, foresters, researchers, educators, and policy- and decision-makers. AKIS supports rural access to innovation (EIP-AGRI, 2022).	Rural roads increase access to productivity-enhancing inputs and markets, and reduce producer and consumer transaction costs in Nepal (Shrestha, 2020).	Vietnam's improvement in market competitiveness has increased producer willingness to adopt innovation (Gray & Jones, 2022).
African countries remain reluctant to adopt GM technology due to unfavorable policies shaped by public opinion and unclear trade frameworks (Gbadegesin et al., 2022).	Insurance and affordable finance reduce the risk of technological adoption and sustain use in times of shock (World Bank, 2022).	Return on investments in forage R&D could be improved by strengthening AKIS through institutional reform and relationship improvement to create access and encourage forage adoption in Colombia (Encisco et al., 2022).	In India, households that access roads diversify production, adopt modern agricultural technologies, and increase hired labor use (Shamdasani, 2021).	Policies that enable competition, innovation, sustainable use of resources, and trade that facilitates the flows of goods, capital, and knowledge, contribute to the adoption of new technologies in OECD countries (DeBoe, 2020).
Stronger intellectual property policy leads to higher levels of innovation (Diaz-Bonilla et al., 2014).	Access to credit consistently has a positive impact on agricultural innovation adoption (Yokamo, 2020).	Evidence in Ghana shows that vigorous extension services are needed to increase uptake of new technologies such as legume inoculants (Mohammed & Abdulai, 2022).	New digital infrastructure in China has demonstrated a positive impact on agricultural efficiency (Ren et al., 2023).	In Sweden, producer perception of competitiveness intensity positively impacts market orientation and lean production orientation, which leads to improved farm performance (Nybom et al., 2021).
Increased market openness and trade have created technology spill-ins in LAC (OECD, 2012).	Provision of education, governance, water, sanitation, health, law enforcement, energy, and ICTs impacts producers' ability to integrate tools into their production systems (Diaz-Bonilla et al., 2014).			
A strong macroeconomic environment creates stability for good functioning markets and investment (OECD, 2020).				

As illustrated in Figure 9, the enabling environment is influenced by external forces and shocks and behavioral influences and vice versa. For example, extreme weather events or conflict and civil unrest can influence policy priorities, available resources, macroeconomic conditions, and physical infrastructure. Conversely, deregulations in the financial sector and increasing demand for agricultural products, including biofuels, exchange rate fluctuations, and global economic growth, contributed to the 2007-2008 food price crisis that created widespread shocks to food systems and food security around the world (Hochman et al., 2014; Brobakk & Almas, 2011).

Research shows that in low-, middle-, and high-income countries alike, producer and food system actor decision-making and behavior related to technological and innovation adoption are highly influenced by the enabling environment. Policies, access to agricultural knowledge, training, goods and services, infrastructure, and market incentives all influence behavior change, particularly by affecting the risk (perceived or actual) of tool adoption. Producer risk aversion and lobbying in the agricultural sector may in turn impact the enabling environment.

TAKE HOME MESSAGE:

The enabling environment needs to be customized to create access to and adoption of productivity-enhancing tools based in part on national drivers of market growth. Factor-driven, efficiency-driven, and innovation-driven economies will require different types of policies, institutions, infrastructure, and strategies, depending on their proximity to the global technological and production frontier (Aghion and Durlauf, 2009; Diaz-Bonilla et al., 2014). Incorporating resilience-enhancing strategies also needs to be at the forefront of planning processes to ensure that gains in productivity are not lost in the face of exogenous shocks. These strategies will vary based on the agroecological and socio-economic conditions of each country.

Behavioral Influences

Even if productivity-enhancing tools are made more accessible by a robust enabling environment, adopting these tools on a sustained basis may require considerable behavior change by producers and other food system actors. Especially in low-income countries, technology and innovation adoption can be associated with modernization and development, which may be at odds with socio-cultural value systems and indigenous production knowledge and priorities (Curry et al., 2021). Action and investment strategies should be tailored to affect factors of behavior change, such as the capabilities, opportunities, and motivators for producers and food system actors to adopt and sustain the appropriate use of productivity-enhancing tools.

Capability, opportunity, and motivation are three factors that have demonstrated an impact on changing behaviors (COM-B) (Michie et al., 2011), including agricultural technology and innovation adoption. **Capability** refers to the psychological (e.g., knowledge, skills) or physical factors (e.g., required equipment, physical strength) that would lead to a producer adopting a productivity-enhancing tool on a sustained basis. **Opportunities** include physical places to acquire the technology, required inputs to apply the technology, affordability and financing, social support of the behavior change (including farmer organizations), and economic and environmental resources (e.g., savings, a water source for irrigation). **Motivation** refers to the internal processes that influence decision-making and behavior change. This includes personal beliefs and perceptions (e.g., risk aversion, technology acceptance), outcome expectations, and self-efficacy (the belief that one has the power to change behavior).

The impact of interventions targeting productivity-enhancing technology and innovation are mediated by COM-B elements as well as characteristics of the producer or other food system actors, the scale of production, and the type of tool. Table 2 gives examples of how behavioral factors affect sustained adoption of various productivity-enhancing tools.

Table 2: Examples of Behavioral Influences on Tool Adoption

CAPABILITIES	OPPORTUNITIES	MOTIVATION
In Ireland, dairy farmers find grassland management practices, such as grass measurement, to be high-effort tasks that are physically taxing, especially among older farmers. Increased skill and knowledge facilitated grass measurement uptake (Regan et al., 2021).	Among Rwandan banana farmers, time and financial resources to own and use a mobile phone, and network availability, negatively impact the adoption of digital extension. However, social opportunity, such as gender norms and cultural view of mobile phone use, was ranked highly (McCampbell et al., 2023).	Trust in the intervening organization impacts adoption rates. In the Netherlands and Germany, government enforcement of microbial applications has a negative impact on adoption, while extension agents and farmer organization training and support have a positive relationship (Tensi et al., 2022).
Knowledge about Western Corn Rootworm control measures among Austrian producers influences the motivation and adoption of the measures (Kropf et al., 2020).	The time cost associated with an irrigation technology set-up in South Africa, despite low financial cost from government subsidies, limits adoption. Digital technologies need to be offered in complementary packages, not discrete applications (de Witt et al., 2021).	In China, risk-averse producers are less likely to adopt new technology and invest less in technology. Farmers with longer-term contracts are more likely to adopt technology (Mao et al., 2017).
Farmers in Ecuador who received text messages on Integrated Pest Management practices have higher knowledge and are more likely to implement the practices than those who did not receive text messages (Larochelle et al., 2017).	Smallholders in Africa, Latin America, and Asia face a $170 billion funding gap as financial providers deem loans too risky or they do not offer products tailored to smallholder producers, especially women (Savoy 2022).	Motivation to adopt climate adaptation practices in western Nepal is positively affected by a producer's assessment of the effectiveness of recommended adaptation practices but negatively affected by their perception of the threat of climate change (Lamichhane et al., 2022).
Education, extension, and training have positive impacts on the adoption of nitrogen management technologies in South Asia (Begho et al., 2022).	Lack of access to quality land, exclusion from decision making, and lack of access to finance constrain women's ability to access and adopt productivity-enhancing rice technologies in East Africa (Achandi et al., 2018).	Misinformation on biotechnology in Kenya has led to resistance to the adoption of improved crop varieties, despite the reversal of nationwide bans in 2022 and a need to tackle historic droughts (Ombogo, 2023).

A FARMER'S PERSPECTIVE

Virginia Grain Producer, Virginia Tech, Class of '95

QUESTION: What should we know from the farmer's perspective about the practicalities of adopting productivity-enhancing tools on the farm?

ANSWER: Improving agricultural productivity is crucial at all scales; however, there are concerns with the feasibility of continually increasing agricultural productivity. Technology is one of the primary methods of increasing production and productivity levels at all scales. However, technology can be difficult to access depending on the scale of the farm. Smaller farms with less liquidity have issues with keeping up with modern technology and often find it difficult to continually add new technologies to their production. New, top-of-the-line equipment that could be crucial to increasing productivity is often expensive and difficult to maintain. For farmers to be willing to invest in new technology, it has to be worth investing in, reliable, and useful over several years.

To continue improving agricultural productivity levels for the smaller scale farmer, technology investments need to be supported across many areas. Overall, there are concerns with new farm technology, and ensuring increasing agricultural productivity will require repeatable, controlled, and consistent technology that is available and affordable at all scales of production.

QUESTION: What would be the most helpful to support you in adopting productivity enhancing tools and technologies?

ANSWER: University led research is a crucial asset for farmers. Technologies discovered through university research tend to be accessible and affordable to farmers. For crop producers, commodity-based research within breeding programs is a key tool for improving productivity. Public breeding programs provide access to improved crop varieties at an adoptable price point. As climate change continues to have impacts on weather patterns, it is crucial that research be conducted to create more resilient crop varieties. More funding needs to be allocated towards agricultural research within universities and public programs. Attempts should also be made to increase collaboration between farmers and public research efforts.

TAKE HOME MESSAGE

Behavioral influences such as capability, opportunities, and motivators will play a critical role in driving sustainable agricultural productivity growth by impacting producer and food system actors' adoption of existing and emerging productivity-enhancing tools. Adoption-oriented interventions, tool development, and ongoing support must be designed in light of the complexity of experiences, beliefs, gender, values, and perceptions of individuals and communities involved in agriculture.

External Forces & Shocks

The uncertainty and risk that producers and other food system actors face in bringing food from farms to the table are well known. The impact of exogenous events on production, such as losing an entire crop to a new disease or pest, motivates the improvement of agricultural knowledge and innovation systems. External shocks and other types of forces also have a direct role in the accessibility and sustained adoption of productivity-enhancing tools. The past several years have demonstrated that climatic variability, extreme weather events, conflict, political uncertainty and volatility, changes in investment, and price and demand fluctuation can cause smallholder producers to fall back down the innovation curve, losing important gains in agricultural productivity.

Fertilizer use, for example, has dropped off significantly in sub-Saharan Africa as a result of the crisis in Ukraine and resulting increases in fertilizer prices (Pinto, 2022). Even in high-income countries such as Canada, the Netherlands, the U.S., Denmark, and the UK, where producers are less economically vulnerable, external forces such as political uncertainty (e.g. unanticipated regulations) act as a deterrent to investing in smart farming technologies (Eastwood & Renwick, 2020).

Behavior and decision-making are largely informed by the perceived threat of external shocks and forces. Especially within smallholder production systems that have significant potential for sustainable agricultural productivity growth, economic vulnerability increases the impact of external shocks (e.g., production, health) on technological adoption. This may discourage producers from ever investing in agricultural innovations, such as modern irrigation technology in China (Tan et al., 2021) or improved seeds in Ethiopia (Gebremariam & Tesfaye, 2018). It could also lead to producers returning to less productive practices and tools due to a lack of affordability or availability.

External shocks and forces also mediate access and adoption by affecting the enabling environment. For example, changes in political regimes transitioning to military rule not only destroy agricultural systems from violence and conflict but also create dysfunctional policy environments and negatively impact trade. Sudan and Niger, for example, are likely to see further declines in agricultural productivity, food insecurity, and household resilience as a result of political volatility coupled with extreme weather events (IFRC, 2023).

TAKE HOME MESSAGE

Policy and investment action to improve agricultural productivity must consider how external shocks and forces may impact the continuity of agricultural innovation uptake to ensure that sustainable productivity gains are not lost and to continue to accelerate returns to the producer, society, the environment, and the economy.

POLICY AND INVESTMENT PRIORITIES

Within the context of the enabling environment, behavioral influences, and external forces and shocks on the accessibility and sustained adoption of proven productivity-enhancing tools, The GAP Report® offers six data-driven policy and investment priorities to inform actionable next steps for policymakers, investors, researchers, implementers, and other interested agricultural productivity enthusiasts.

Invest in public agricultural R&D and extension services	Public sector agricultural R&D and extension services generate innovation and information that facilitate environmentally sustainable agricultural output growth, improve human health, and support a vibrant agricultural economy.
Embrace science- and information-based technologies and practices	Science- and information-based technologies and techniques enable producers of all scales to manage environmental and economic risks by improving their sustainability, resilience, and competitiveness.
Improve the infrastructure and market access for agricultural inputs and outputs	Efficient transportation, communications, and financial infrastructures, and affordable and equitable access to markets for agricultural inputs, services, and outputs, support sustainable economic growth, diminish waste and loss, and reduce costs for producers and consumers.
Cultivate partners for sustainable agriculture and improved nutrition	Public-private-producer partnerships supporting agricultural development, gender equity, and nutritious food systems leverage public and private investments in economic development, natural resource management, and human health.
Expand and improve regional and global trade	Forward-looking trade agreements, including transparent policies and consistently enforced regulations, facilitate the efficient and cost-effective movement of agricultural inputs, services, and products to those who need them.
Reduce post-harvest loss and food waste	Reducing post-harvest losses and food waste increases the availability and affordability of nutritious food, eases the environmental impact of food and agricultural production, and preserves the value of the land, labor, water, and other inputs used in the production process.

PARTNER STORIES

GAP Report® partners offer real-world examples of innovations that improve the access to and adoption of proven productivity-enhancing tools. Their work demonstrates that implementing appropriate and science-based tools can improve farmer livelihoods, strengthen environmental resilience, and contribute to economic stability.

Photo: Bayer Crop Science

Better Life Farming—Unlocking Smallholder Farmers' Potential

Bayer Crop Science

Smallholder farmers face significant challenges, including limited access to high-quality agricultural inputs and knowledge of Good Agricultural Practices (G.A.P.). To effectively support smallholders in unlocking their full potential, a holistic ecosystem approach and the expertise and services of a variety of partners is required. That's the focus of Bayer's Better Life Farming Alliance (BLF): to deliver tailored, local solutions and advisory tools at the village level to enable smallholders not only to increase their productivity, but to build commercially viable, sustainable farming businesses, and improve their livelihoods.

Photo: Bayer Crop Science

How a Small Change in Cattle Feed is Transforming Ranchers' Lives in Mexico and Central America

Bayer Crop Science

Every year, the dry season in Central America slows milk production–and climate change is exacerbating the problem. What if dairy farmers planted corn during the rainy season, produced silage, and saved it for the next dry season to feed their herds? Through Bayer's DKsilos initiative, small-scale cattle ranchers are learning how to grow corn, which comes with shared value for all involved parties along the dairy value chain. As a result of this initiative's implementation, participants of the program have reported increased incomes and improved quality of life.

Photo: Corteva Agriscience

Sustainable Innovations for Smallholder Farmers

Corteva Agriscience

Corteva researchers are collaborating with global agricultural research institutions to bring sustainable innovations to smallholder farmers facing some of the greatest pest, disease, and climate challenges. Together, we are co-developing new seed varieties, which will provide vital nutrition to food-insecure regions around the world. Through these collaborative research efforts, Corteva is advancing its mission to enrich the lives of those who produce and those who consume for generations to come.

Photo: Corteva Agriscience

Strengthening Smallholder Markets in Argentina

Corteva Agriscience

Corteva is leading a collaboration with key stakeholders in Argentina to improve the productivity and incomes of smallholder farmers in the provinces of Salta and Corrientes. Although growing conditions in these regions are favorable for corn, farmers often lack access to climate-optimized seed, sustainably advantaged crop protection products, and agronomic training. They also face challenges with harvesting, warehousing, and access to finance. This collaboration is strengthening the market system while advancing Corteva's mission to enrich the lives of those who produce and those who consume for generations to come.

Photo: John Deere

From Farm to Phone: The Future of Connected Farms

John Deere

Connectivity is critical to meeting global food demand, which is expected to increase 50 percent by 2050, as the world population is projected to significantly grow. Satellite connectivity is key to helping farmers take advantage of cutting-edge technologies such as artificial intelligence (AI) and machine learning. Connectivity enables farmers to use these technologies to turn information and data into actionable insights to meet growing global food demands. John Deere plans to leverage satellite connectivity technology to enable farmers around the world to take advantage of technology as Deere works toward their goal of connecting 1.5 million machines by 2026.

Photo: Farm Foundation

The Farm Foundation: Supporting Emerging Voices of the Agricultural Industry

Farm Foundation

The legacy of the Farm Foundation spans across nine decades, with a mission of providing comprehensive information to agricultural private and public sectors as well as consumers around the world through forums, online resource centers, and annual reports. Since its inception in 1933, the organization's programs have been used to respond to varying needs of food and agricultural practitioners, rural populations, and global citizens. Some of these programs include the Young Farmer Accelerators Program, the Agricultural Economics Fellowship, and bi-annual roundtable meetings for thought leaders. These programs tackle the diverse needs of consumers and explore such topics as international trade.

Spearheading Anemia Zero with Biofortified Potatoes in Peru

International Potato Center

The Anemia Zero campaign in Peru aims to combat anemia, a prevalent health issue, by promoting healthy and diversified diets amongst vulnerable populations. The International Potato Center (CIP), a global research-for-development organization, is developing biofortified potato varieties enriched with iron using conventional breeding techniques. CIP conducted a pilot study to facilitate the dissemination of advanced clones of these varieties to farmers in Northern Peru while collaborating with government extension agencies, health clinics, social protection programs, and local communities to promote awareness and acceptance. CIP's contributions are crucial to achieving the Anemia Zero campaign's objective of eradicating anemia in Peru.

Photo: HarvestPlus

Increasing Access to Nutrient-Enriching Technology to Bring Resilience to Food Systems

HarvestPlus

Farmers face compromised livelihoods and nutrition security amid climate change and other challenges. Biofortified crops are bred with a greater density of micronutrients and climate-adaptive traits that improve their resiliency. Over 100 million people in farming households are now eating biofortified foods. To increase access to biofortified varieties, HarvestPlus is facilitating market linkages and driving awareness via social and digital media. Nutrient-enriched, high-yielding varieties such as zinc wheat and vitamin A cassava can strengthen staple food production and improve livelihoods and food systems inclusivity to address global hidden hunger.

Photo: Heifer International

Guatemala: Increasing Incomes, Breaking with Traditions

Heifer International

While one-third of Guatemala's population is employed in the agriculture sector, many small-scale producers have limited access to the tools necessary to establish profitable enterprises. This includes the country's spice producers, who have been hampered by longstanding price volatility alongside challenges such as climate change and the COVID-19 pandemic. Heifer International works with spice producers through its Green Business Belt (GBB) project, which, paired with traditional extension services, supports producers in building resilience to market fluctuations. As a result of the initiative, 62 percent of project households were able to close the gap between their actual income and Living Income benchmarks.

Photo: IICA

Delivering Safe Tools for Farmers Through Institutional and Regulatory Innovation

Inter-American Institute for Cooperation on Agriculture

Farmers in Latin America and the Caribbean are interested in using safe tools to improve the quality and resilience of crops and adapt to climate change. The Inter-American Institute for Cooperation on Agriculture (IICA) is supporting 34 member states in the Americas to implement science-based regulatory systems and create a policy environment that promotes technology adoption, which contributes positively to agricultural productivity growth. With technical cooperation and training, countries such as Honduras are becoming leaders in the use of agricultural biotechnologies that help farmers use less pesticides, require less labor, and earn higher net profits. IICA has organized seminars with regulators from 17 countries of the Americas.

Photo: IFDC

Space to Place, an Initiative for Increasing Fertilizer Use Efficiency

International Fertilizer Development Center (IFDC)

The Space to Place Initiative, part of the USAID-funded Feed the Future Sustainable Opportunities for Improving Livelihoods with Soils (SOILS) activity, is led and implemented by IFDC (2023-25). The initiative aims to provide recommendations on soil fertility technologies in key production systems of sub-Saharan Africa. The primary goal is to reduce fertilizer wastage at the farm level by 60 percent through improved use efficiency for optimal economic returns and improved productivity. The approach enables the delivery of spatially appropriate soil fertility management recommendations, guided by soil maps (Space) combined with farm(er)-level characteristics (Place). The major outcome is a space-to-place decision support tool (S2P-DST) for resource-constrained smallholders that delivers hyper-localized soil fertility recommendations.

Photo: Mosaic

Soil Monitoring Technology and Real-time Data Improve Outcomes for Farmers and the Environment

Mosaic

The Mosaic Company, in partnership with academia and a global NGO, has invested in a program to introduce technology to farmers in Florida, United States, to maximize the impact of water and fertilizer inputs. Soil probes and digital dashboards offer real-time access to soil salinity and moisture data so farmers can make more informed decisions about water and fertilizer applications–with benefits for both the farmer and the environment. Mosaic and its partners plan to scale the program to other regions to promote the technology and best management practices for nutrient stewardship and irrigation management.

Photo: Purdue University

Engaging Hard-to-Reach Farmers through Scientific Animations without Borders

Purdue University

Total Factor Productivity (TFP) can be effectively increased through the adoption of technological advances by marginalized smallholder farmers. Scientific Animations Without Borders (SAWBO™) is an effective tool for communicating technology and best practices in agriculture for particularly hard-to-reach farmers. SAWBO™ transforms extension information on relevant topics into 2D, 2.5D, and 3D animations, which are then voice overlaid into an array of languages. SAWBO™ covers a range of topics, such as agriculture, economics, health, women's empowerment, peace and justice, and climate change resilience. Evaluations have proven a high level of technology adoption by farmers receiving and sharing animations on their mobile phones. For example, in Benin, 70 percent of the farmers adopted steps to apply neem as a natural pesticide after viewing a SAWBO™ animated video (Bello-Bravo et al., 2017).

Photo: SSA

Digital Solutions for Effective Extension and Advisory Service Delivery Among Farmers in Ethiopia

Sasakawa Africa Association

In Ethiopia, in partnership with Amplio, the Sasakawa Africa Association (SAA) introduced the Amplio Talking Book (ATB), a digital solution for sharing agronomic information with farmers. The pilot launched in 2020, when 1,260 (30 percent women) farmers from the Angacha and Ana Sora districts received ATBs with 16 pre-recorded messages on regenerative agriculture, nutrition-sensitive agriculture, and market-oriented agriculture. The battery-operated ATB serves as a "radio" that also supports the collection of user feedback and enables SAA to modify its programming in near real-time–with the ultimate aim of improving productivity through increased access to extension information.

Photo: S M Sehgal Foundation

Complementary Productivity-enhancing Solutions Provide a Pathway to Sustainable Agriculture Among Indian Farmers

S M Sehgal Foundation

S M Sehgal Foundation's Agriculture Development Program is promoting improved access to sustainable agriculture for smallholder farmers in India. The Foundation developed the Package of Practice (PoP) approach to increase farm-level productivity, improve profitability, and promote better stewardship of the environment. The program provides farmers training and access to a suite of complementary productivity-enhancing tools that promote soil health and resource conservation. The PoP approach provides farmers information on valuable practices such as soil management, small-farm mechanization, water-efficient irrigation techniques, livestock management, and information and communication technologies.

Photo: Smithfield Foods

Increasing Productivity While Reducing Greenhouse Gas Emissions

Smithfield Foods

Smithfield Foods has been on the forefront of sustainability solutions for more than two decades and has become increasingly focused on capturing methane, a potent greenhouse gas (GHG), from the hog manure on its farms. The company has been rapidly adding anaerobic digesters on its company-owned operations to capture natural emissions from manure and convert them into pipeline-quality, low-carbon renewable natural gas (RNG). These projects will better protect the environment and benefit surrounding communities by reducing methane emissions, providing a diverse income stream for family farmers, and producing clean, low-carbon energy to power homes and businesses.

Unlocking Research through Innovative Partnerships to Address Methane Emissions

SoAR Foundation

Enteric methane is a leading cause of agricultural greenhouse gas emissions. These emissions, produced by the digestive system of ruminants–namely cattle–are difficult to mitigate long-term. The Innovative Genomics Institute (IGI) at UC Berkeley, in collaboration with UC Davis, is developing an innovative process that alters the microbiome of cattle rumen to reduce methane emissions, an intervention that can reduce emissions over the animal's lifespan. Through a partnership with the Global Methane Hub, IGI is leveraging its resources to accelerate complementary research globally through the Enteric Fermentation R+D Accelerator, a new philanthropic initiative launched through AIM for Climate.

Photo: Tanager

Addressing the Gender Gaps in Agriculture to Improve Productivity

Tanager

Women make up over one-third of primary producers in agriculture yet remain marginalized within the sector, often lacking decision-making power, access to mechanization, access to information on agricultural best practices, and more. The Impacting Gender and Nutrition through Innovative Technical Exchange (IGNITE) project–implemented by Tanager, Laterite, and 60 Decibels–is offering tailored technical assistance to African agricultural institutions to mainstream gender and nutrition into their interventions, systems, and operations. Based on research findings from IGNITE, recommendations are provided to enable all agricultural institutions to similarly apply a gender lens to their work as a pathway to increasing agricultural productivity.

Photo: Daugherty Water for Food Institute, University of Nebraska

Challenging Assumptions in Farmer-led Irrigation: The Value of Informal Equipment Rental Markets

Daugherty Water for Food Institute, University of Nebraska

Farmer-led irrigation focuses on small-scale, local, and contextual irrigation solutions to improve livelihoods and food security. Subsidies, pay-as-you-go schemes, and grants are often used by farmers to purchase irrigation equipment in sub-Saharan Africa. However, it may not always make sense for smallholders to own irrigation equipment. The Daugherty Water for Food Global Institute's research challenges the assumption that ownership provides the maximum utility to smallholders. The research explores businesses that provide irrigation as a service, in which farmers in Rwanda lend and rent small pumps in informal markets, with the goal of finding scalable, farmer-led solutions to increase irrigated agriculture.

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