VULNERABLE AGRICULTURAL SYSTEMS REST ON FRAGILE FOUNDATIONS

Global agricultural systems are being rocked by COVID-19, climate change, extreme weather events, and conflicts in Ukraine and elsewhere, driving up prices for food and agricultural inputs.

The agricultural systems of high- and upper-middle-income countries are withstanding the shocks relatively well. However, food insecurity, malnutrition, and poverty rates have risen sharply, especially in low-income countries since 2020. In 2022, 40 million people faced emergency or catastrophic levels of food insecurity, twice as high as in 2020 and six times more than in 2016 (Food Security Information Network, 2022).

The troubling trends in agricultural productivity growth are mainly unnoticed; updated data reveals that the world’s shock-sensitive systems rest on increasingly fragile foundations. Reversing the downward trajectory of global agricultural productivity growth demands urgent action from policymakers, leaders, donors, scientists, farmers, and others in the agri-food system.

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Global agricultural productivity growth is in steep decline.

To sustainably produce food and agricultural products for more than 9 billion people in 2050, agricultural productivity must increase an average of 1.73 percent annually. From 2011-2020, global agricultural productivity grew at an average of just 1.12 percent per year, a significant drop from the average growth rate of 1.99 percent from 2001-2010 (USDA ERS).

Productivity growth is not scale-dependent.

The prospects for agricultural productivity growth are not exclusive to large farms. An increasing number of agricultural technologies and farm management services are designed for use at smaller scales. Unfortunately, most small-scale producers cannot access the innovations and information they need to ensure a productive, profitable, and sustainable future (Fuglie et al., 2020).

Extreme climate events disrupt productivity gains.

New research by Wei Zhang, assistant professor of agricultural and applied economics at Virginia Tech, shows that extreme climate events are estimated to have, on average, a negative and statistically significant impact on the TFP growth rate (See page 11). The estimated impact of droughts is more than three times the impact of an average extreme climate event. These climate shocks can have a sustained effect on the growth trajectory of agricultural productivity.

Regional differences in productivity growth reveal areas of concern, alarm, and hope.

Productivity growth is no longer the primary driver of agricultural output growth in Latin America and the Caribbean. Instead, regional producers rely on input intensification, applying more inputs (labor, fertilizer, capital) per hectare of land to increase output.

In sub-Saharan Africa, agricultural output grew a healthy 2.98 percent per year (2011-2020). However, most of the growth was driven by opening up new land for cultivation and pasture, while agricultural productivity contracted by 0.12 percent annually. Converting grasslands, forests, and other wildlands to agricultural production can decrease biodiversity and wildlife habitat, and increase soil degradation and erosion.

South Asia, especially India and Bangladesh, has had steady productivity growth since 2001. TFP grew by an average of 2.34 percent annually from 2001-2010, remaining steady at 2.28 percent annually from 2011-2020.

Alarmingly, global agricultural productivity growth has fallen well below the level needed for sustainable growth of agricultural output.

Productivity growth supports resilience during system shocks.

Agricultural productivity-enhancing innovations and services reduce risks for producers and support resilience. This includes drought-tolerant seed varieties, drip irrigation systems, cover crops, improved animal genetics, mobile phone-based extension programs, and access to financial and insurance services.

Current efforts to accelerate productivity growth are inadequate to the scope of the challenge.

Governments, the private sector, research institutions, international development organizations, and civil society groups must take urgent and vigorous action to accelerate productivity growth. Only then can the world be assured that its agricultural systems are sustainable and resilient to shocks.
generated by more efficient use of land, fertilizer, or livestock reflects progress toward a more sustainable approach to agricultural production.

The 2022 GAP Index reveals the lowest level of TFP growth to date, an average of 1.12 percent per year (2011–2020), far below the target of 1.73 percent annual growth (Figure 2). If this rate remains unchanged, the gap will widen over time, making it increasingly difficult to close. The implications of this growing gap are the widespread use of unsustainable agricultural practices, including the conversion of wild and marginal lands to agricultural production. As a result, a portion of the gap will remain unfilled, leading to unacceptably high levels of hunger, malnutrition, and rural poverty.

Explore productivity by country via our interactive map

Figure 1: Total Factor Productivity

TROUBLESOME TRENDS IN TFP GROWTH

Agricultural productivity growth will be the linchpin of strengthening the world’s agricultural systems in the next decade. It increases producers’ incomes, can lower consumer costs, and reduces the environmental impact of food and agricultural production.

Agricultural productivity growth, measured as total factor productivity (TFP), increases when producers increase their output of crops, livestock, or aquaculture products, using the same amount or less land, labor, capital, fertilizer, feed, and livestock (Figure 1).

In other words, TFP rises when producers utilize innovative agricultural technologies to increase output with the same amount or fewer resources. For example, healthy animals produce more meat so that the farmer can increase their output without additional animals. By combining precision equipment, data analytics, and advanced seed varieties, producers know when to plant, where every seed is located, and the exact amount of fertilizer or crop protection products needed in every section of the field.

Since TFP incorporates a range of inputs and outputs in its calculation, it is “the broadest available measure of technical efficiency and productivity over time” (Fuglie & Steensland, 2022). As a result, tracking changes in TFP reveals a great deal about agricultural systems.

First, an increase in TFP shows that a large and increasing number of producers are adopting new technologies and practices. This also indicates the extent to which new technologies are accessible to farmers. It may also show the effectiveness of farmer training and extension systems.

Second, TFP growth makes the agriculture sector, including producers, more competitive by lowering 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 can also benefit since the per-unit price for the producers works its way through the value chain, influencing the prices consumers pay.

Third, TFP encompasses three inputs that contribute significantly to agriculture’s environmental impact: land, fertilizer, and livestock. Therefore, an increase in TFP

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TFP growth rates have declined for all country income groups, but low-income countries, where TFP has contracted by 0.04 percent annually during 2011-2020, are of significant concern. This contraction in TFP growth may exacerbate the already high levels of food insecurity and malnutrition and threaten the prospects for economic development in these nations. The experience of China and Southeast Asia shows that the agriculture sector can be a driving force for economic growth if producers can access innovations and services to increase their productivity (Fuglie et al., 2012). Given the current negative TFP growth rate in low-income countries, it is clear that current approaches are not sufficient.

The middle-income countries have rates of TFP growth above the global average yet less than the global target. Productivity growth has slowed in two regions that experienced high TFP growth in the 2000s: China and the countries of the former Soviet Union (See page 5).

A GLOBAL VIEW OF TFP TRENDS

To appreciate the role of total factor productivity growth in agricultural systems, it is helpful to compare agricultural output and input use over time (Figure 3). Since 1961, gross agricultural output has increased four-fold while input use has slightly more than doubled. The distance between the two lines reflects the output that
can be attributed to the efficient use of agricultural inputs, some with a substantial environmental impact: land conversion, fertilizer, and livestock. In other words, TFP growth. Moreover, comparing agricultural input to output use over time demonstrates the essential role of TFP growth in the sustainability of agricultural systems (Fuglie et al., 2012).

Agricultural productivity growth is the primary source of global agricultural output growth since the 1990s (Figure 3). When TFP grows, land expansion can be limited or eliminated, and fewer inputs are needed on each acre of agricultural land. Extension of irrigation, especially in China, supported TFP growth and allowed producers to intensify their crop rotations, producing more crops on the same plot of land.

In contrast to global trends shown in Figure 3, low-income country agricultural output growth (more than 400 percent since 1961) has relied largely on increasing inputs, especially land expansion, arguably the least sustainable way to grow agricultural output. TFP growth in low-income countries continues to lag well behind the rest of the world, and suggests that agricultural sustainability and food security will continue to be elusive (Figure 4).

The most recent data show a sharp decline in TFP and output growth (Figure 5). The average annual TFP growth rate declined from 1.99 percent in 2001–2010 to 1.12 percent in 2011–2020. The contribution of land expansion (much of this in Sub-Saharan Africa) to output growth more than doubled between the two decades, while the rate of input intensification declined by 17 percent.

In addition to the significant drop in TFP growth, the USDA Economic Research Service is reporting for the first time that agricultural output grew by less than 2 percent (average annual growth, 2011–2020). This raises concerns about the prospects for reducing the recent increases in food insecurity and malnutrition. It is important to note that these data reflect impacts from only the first nine months of the COVID-19 pandemic, and no influence from the Russia-Ukraine war. In other words, the 2011–2020 TFP data illustrate a worrisome global trend of declining TFP growth. Climate change and other types of resource degradation may be taking a larger toll on productivity as well as a slower pace of change in the development and adoption of improved technology.

At the start of the twentieth century, producers around the world opened up new land for cultivation and grazing to increase their output. Then in the 1960s, the Green Revolution gave millions of farmers access to effective pesticides, fertilizer, and irrigation, sharply increasing output and preventing mass starvation (Figure 5). Subsequently, improved technologies and practices enabled producers to use their land and inputs more efficiently (i.e. TFP increased). By the 1990s, global agricultural productivity growth was the primary driver of

**Figure 3:** Global Agricultural Outputs, Inputs, and Total Factor Productivity (TFP), 1961–2020

**Figure 4:** Low-Income Country Agricultural Output, Input, and Total Factor Productivity, 1961–2020
global agricultural output growth, and was well above the target 1.73 percent annual growth during 2001-2010. However, as noted above, TFP growth declined sharply during 2011-2020.

The Organisation for Economic Co-operation and Development (OECD) is predicting 1.4 percent annual growth in food demand during 2022-2031, mostly due to population growth. Total agricultural output growth averaged 1.93 percent during 2011-2020 (Figure 5). According to OECD’s population growth projections (Figure 6), world per capita GDP growth will exceed population growth, meaning that net per capita income should increase worldwide. This trend is predicted to be especially pronounced in India, China, and Southeast Asia. In contrast, population growth in Sub-Saharan Africa will be more than twice that of GDP. Thus, increasing TFP growth will be especially critical in this region to meet food demand and maintain an affordable food supply while protecting the natural capital on which agricultural production relies.

TFP TRENDS BY REGION

Examining TFP growth in key regions provides additional perspectives on productivity trends (Figure 7). Although global TFP growth during 2011-2020 was alarmingly low at 1.12 percent, TFP growth continues to be robust in South Asia and the Transition Countries (former Soviet Union) at 2.28 percent and 1.89 percent, respectively. In China, TFP growth was under 1 percent in the 1970s, and Transition Countries were experiencing negative TFP growth as recently as the 1990s. Market-driven policy changes have sparked a TFP transformation in these countries. Yet history shows that once these changes are integrated into the agricultural sector, TFP growth will slow down. China is a case in point. China’s TFP growth averaged 2.48 percent from 2001 to 2010, falling to 1.59 percent from 2011-2020. The next challenge for countries is maintaining a steady rate of TFP growth through continued policy improvements and investments in agricultural R&D.

Sub-Saharan Africa is a cautionary tale in this regard. Policy reforms in the 1980s and 1990s generated annual TFP growth rates of greater than 0.65 percent during 1980 through 2010, but with minimal investments in agricultural R&D, the
region has been unable to sustain or improve TFP growth. The region is now experiencing negative TFP growth. Countries that have invested in the success of emerging farmers (market-oriented, cultivating five to 20 hectares) have made significant strides in TFP growth, including South Asia and Southeast Asia. Sub-Saharan Africa has a small but active population of emerging farmers. These farmers have the most potential for productivity growth, but urgently need access to improved technologies and agronomic information, as well as an enabling policy and trade environment for TFP growth.

In Sub-Saharan Africa, underinvestment in agricultural research and development and farmer training throughout most of the continent has left farmers with few options for increasing output (Fuglie and Rada, 2013). With limited access to productivity-enhancing technologies such as mechanization, advanced seeds, fertilizers, and improved livestock breeds and feed, farmers are expanding crop and grazing lands at an alarming rate, with negative impacts on biodiversity.

In South Asia, TFP grew at a robust average annual rate of 2.28 percent during 2011–2020, essentially the same growth rate as during 2000–2010. Input intensification and irrigation extension are also contributing significantly to output growth. Extending and improving India’s irrigation systems boosted productivity on already cultivated land. Increased access to mechanization services and improved seed genetics have reduced the need for agricultural labor. Land expansion for agriculture is now near zero.

The rate of TFP growth in North America has slowed from 1.6 percent annual growth during the 1990s and 2000s to a paltry 0.16 percent during 2011–2020. The slowdown coincides with decreased public-sector agricultural research and development investments—the cornerstone of TFP growth. According to the USDA Economic Research Service, in 2019 U.S. public agriculture and food R&D expenditures in constant dollars reached its lowest level since 1970. A renewed commitment to public investment in agricultural innovations, especially in the United States, is crucial to return to robust TFP growth. Furthermore, U.S. agricultural R&D innovations can benefit other countries as well.

Similar to North America, TFP growth in Latin America and the Caribbean (LAC) was robust, growing at more than 2 percent annually during 1991–2010. Precision agriculture, advanced seed technologies, and improved livestock management systems have driven substantial TFP growth in feed grains and livestock production in countries such as Brazil and Chile. However, during 2011–2020, TFP growth in LAC decreased to less than 1 percent annually, and input intensification became the leading contributor to agricultural output growth.

TFP growth in Europe remains sluggish at about 1 percent annually. Output and TFP growth have been strong in breadbaskets of the former Soviet Union, particularly Russia and Ukraine, far above those of EU countries. However, the current Russia-Ukraine conflict is creating input and food supply and price crises globally, and will undoubtedly reduce TFP growth. The full impact of the conflict remains to be seen.

**Figure 7: Sources of Agricultural Output Growth by Region, 2011–2020**

![Figure 7: Sources of Agricultural Output Growth by Region, 2011–2020](image-url)

Source: USDA ERS, 2021
STORIES OF PARTNERSHIP AND PRODUCTIVITY GROWTH

Accelerating agricultural productivity growth is a complex challenge requiring collaborative solutions. The GAP Initiative partners and friends work around the world with government, industry, research institutions, and civil society to create an enabling environment for producers to access the innovation and knowledge they need to thrive. Below is a sample of some of the partnership stories.

INCREASING ACCESS TO HYBRID MAIZE AND WHEAT SEED IN ETHIOPIA

SUBMITTED BY: Corteva Agriscience

Ethiopia is facing a 4-year drought, the most severe in 40 years, accelerating food insecurity for more than 13 million people. To increase food security and resilience, smallholder farmers in Ethiopia must produce more staple grains, such as corn and wheat. Corteva is part of an alliance with USAID, ACDI/VOCA, Corteva, John Deere, and Hello Tractor to increase the productivity of targeted smallholder farmers by 70 percent and their incomes by 40 percent. The program will also address the enabling environment for local seed production and work with a range of stakeholders to improve policies and address market barriers so that farmers can have an adequate and reliable supply of high-quality seeds. Smallholder farmers will be encouraged to adopt yield-optimized and climate-adaptive hybrid seeds, improve agricultural management practices, and access agricultural mechanization services to minimize post-harvest losses. The alliance also strives to improve access to credit and enhance market linkages so farmers can sell what they produce and consumers can buy what they need to feed their families.

THE DASHBOARD FOR AGRICULTURAL WATER USE AND NUTRIENT MANAGEMENT

SUBMITTED BY: Daugherty Water for Food Global Institute, University of Nebraska

Researchers at the Daugherty Water for Food Global Institute (DWFI) and their partners are working to help growers worldwide achieve critical food production goals while overcoming environmental challenges and keeping farms profitable. The Dashboard for Agricultural Water Use and Nutrient Management (DAWN) project aims to provide farmers with a powerful, predictive decision-making support tool. Project collaborators hope to produce more accurate seasonal forecasts, up to nine months in advance, and one to six-day forecasts during the growing season. These more reliable forecasts help growers optimize crop productivity and manage risk. DAWN is supported by the United States Department of Agriculture-National Institute of Food and Agriculture and is a collaborative effort among several universities and organizations.
PARTNERING FOR SOIL HEALTH AND PRODUCTIVITY

SUBMITTED BY: The Mosaic Company

USDA describes soil health “as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.” Over the years of cultivation, soil health can decline due to intensive tillage, chemical application, overgrazing, and deforestation. Soils with a weakened biome are less able to mobilize nutrients from organic matter, including but not limited to nitrogen, carbon, and phosphorus. The misuse of fertilizer can lead to runoff, ammonia volatilization, and denitrification resulting in polluted waterways and nutrient deficiencies for crops. 4R practices might include a soil testing regime to confirm the next crop’s nutrient demand. Another method involves placing fertilizer at the seed where it is most needed. Both these methods minimize the loss of nutrients and maximize the use of resources. Techniques learned through the 4R Nutrient Stewardship program allow an Illinois farmer to decrease costs per acre between $16.49 and $25.31 while reducing greenhouse gas emissions (CO2E) by 34.7 percent from 9.4 CO2E per bushel to 6.14 CO2E per bushel of grain.

FROM THE SOUTHERNMOST RICE REGION IN THE WORLD: INNOVATION GROWS CLIMATE-SMART RICE

SUBMITTED BY: Inter-American Institute for Cooperation on Agriculture (IICA)

Rice is one of the most important staple grains consumed worldwide, feeding more than half the world’s population. Conventional production requires significant amounts of water. A megadrought that has lasted more than a decade in the central valley of Chile threatens the sector, and climate change presents more significant challenges for productivity. To respond to these challenges, Chile’s national agricultural research institution (INIA) and the Inter-American Institute for Cooperation on Agriculture (IICA) are helping the growers of the rice regions of Maule and Ñuble increase productivity by generating innovations in the management of water resources and other elements of rice production. The sector is now meeting these challenges through participatory research, agronomic innovation, and cooperation in a climate-smart production system known as SRI (System of Rice Intensification).

CLIMATE-SMART POTATOES AND SWEETPOTATOES BOOST RESILIENCE IN THE TROPICS

SUBMITTED BY: International Potato Center

Potato and sweetpotato are essential in nourishing burgeoning populations in Africa and Asia. Their attributes should ensure they’ll contribute to food and nutrition security as climate change challenges farmers’ ability to feed their families and compatriots. Potato and sweetpotato produce more calories per hectare than rice or wheat, with less water. But their most significant attribute, in the long run, may well be resilience. For example, the International Potato Center (CIP) has partnered with breeding programs across the globe in tapping potato and sweetpotato biodiversity for the development of robust, productive, and nutritious varieties, improving the livelihoods of about 10 million farming families to date.

RECOMMENDATIONS FOR TRANSFORMING THE FOOD SYSTEMS OF A CRISIS-STRICKEN WORLD

SUBMITTED BY: CIMMYT

Agriculture and food production is of the utmost importance to peace and prosperity. The crisis in Ukraine has abruptly reminded the world that food systems are interdependent and vulnerable to market shocks like the one triggered, in this case, by conflict. The food security impacts of the current crisis are likely to reverberate over months, if not years, and to be most deeply felt by vulnerable communities in the Global South. To increase resilience in the medium term, there should be a targeted expansion of agricultural production within agroecological boundaries. In addition, the world must invest heavily in research and capacity development for agricultural resilience to combat malnutrition and overcome the recurring threat of food insecurity driven by climate change and conflict.
A PARTNERSHIP FOR PRODUCTIVITY, SUSTAINABILITY, AND PRODUCTIVITY
SUBMITTED BY: Smithfield Foods

Smithfield Foods is working to introduce holistic regenerative agricultural solutions to reduce carbon emissions by 25 percent as of 2025 and become carbon negative by 2030. Smithfield buys more than 10 billion pounds of grain each year, accounting for approximately 15-20 percent of the company’s total carbon footprint. The principal consumption of grain presents an opportunity for sustainable adaptation. While fertilizer is an essential tool for agriculture to replace the nutrients extracted by the previous harvest, conventional fertilizer is also a significant driver of crop-related GHG emissions. In 2013, Smithfield and the Environmental Defense Fund created the SmithfieldGro Program to improve environmental quality by empowering farmers with the agronomic tools to optimize nutrient absorption, utilize less fertilizer, improve soil health, reduce water, and improve water quality. By 2018, Smithfield directly engaged 80 percent of its grain suppliers about sustainable fertilizer and soil health practices.

GIVING SMALLHOLDER FARMERS ACCESS TO ALL TOOLS WILL HELP ACCELERATE AGRICULTURAL PRODUCTIVITY GROWTH
SUBMITTED BY: Bayer Crop Science

Agricultural productivity in smallholder farming systems has been severely declining for the past decade. According to recent data, the Global South is struggling, with the annual average TFP growth rate down by 52 percent from 2011-2020 compared to the previous decade of 2001-2010. One primary reason for the declining productivity is the lack of access by smallholders to all new and old tools needed to address a wide range of productivity-related challenges. At Bayer, several tools have been developed that would significantly improve the agricultural productivity of smallholder farmers. Among these are the smart corn system for withstanding severe weather conditions, tools for precise in-season management of fertilizer and crop protection needs, and genetically engineered maize for insect resistance and drought tolerance. Many of these tools cannot be accessed by farmers because of the lack of enabling policy environment in most smallholder farming countries.

TESTING IRRIGATION TECH: KANSAS FARMS DEMONSTRATE WATER SAVINGS
SUBMITTED BY: John Deere

A recent survey of irrigated growers in Kansas found that nearly all thought it was essential to conserve water but also believed they were already doing all they could. Seventeen of those irrigators are now involved in an educational effort to prove them wrong. The Kansas Water Office launched the effort in 2016 with these Water Technology Farms charged with testing—and demonstrating—the latest in irrigation management and technology. The farms compare various center-pivot irrigation nozzles, soil moisture sampling methods, irrigation scheduling approaches, aerial imagery, and more. Concerns over water quantity and quality spurred father and son partners Eugene and Ryan Goering to enroll their farm near Moundridge, Kansas. “We want to conserve water and optimize efficiency as much as possible and help other farmers see what tools can best benefit them,” says Ryan. “We’ve experimented with 80 percent and 90 percent of the rated application rate and have seen no difference in yield, so we’re confident we could cut back water use by at least 10 percent and maybe more,” says Ryan.
IN ZAMBIA, STRENGTHENING FOOD AND NUTRITION SECURITY FOR REFUGEES AND HOST COMMUNITIES

SUBMITTED BY: HarvestPlus

Zambia hosts refugees from DR Congo, Angola, Burundi, Rwanda, and more countries in three UNHCR settlements in the country’s western and northern parts. A HarvestPlus partnership supports refugees and their host communities with humanitarian supplies of vitamin A-enriched orange sweet potato (OSP) and the means to grow it for improved food and nutrition security. Smallholder farmers in the refugee settlements will also benefit from the opportunity to sell their OSP vines on the market, providing a vital livelihood boost. HarvestPlus is delivering essential training in nutrition and agronomy to 1,300 lead farmers in the settlements. The trained lead farmers will pass on their learned skills to their many follower farmers within the settlement areas.

PROMOTING SUSTAINABLE AGRICULTURE PRACTICES AMONG SMALLHOLDER FARMERS IN INDIA

SUBMITTED BY: S M Sehgal Foundation and Mosaic India Pvt. Ltd.

A large percentage of India’s population still depends on agriculture as their primary source of income. The majority are small-scale farmers. The crucial challenge for India’s development is ensuring that these farmers can gain adequate remuneration from farming and contribute to the country’s growth, while continuing to build their resilience toward the many challenges agriculture faces, including climate change. The *Krishi Jyoti* (enlightened agriculture) project brings the basic principles of modern agriculture to farmers to improve the productivity of their fields with the use of balanced soil nutrients and advice about other better farming practices, including the use of quality seeds. The average increase in crop productivity observed was 15 to 26 percent for various crops.

TODAY’S INVESTMENT IS TOMORROW’S PROSPERITY

SUBMITTED BY: Supporters of Agricultural Research Foundation (SOAR)

Agricultural research and development investment in the U.S. is uniquely a domestic and global concern. U.S. publicly funded agricultural R&D drives most domestic agricultural innovation but is also the engine that drives much of global agricultural progress. Current investment trends, however, are not rising to the challenge. Closing the investment gap and accelerating global total factor productivity gains will take a sustained but achievable approach—such actions pay dividends. Recent modeling from the Breakthrough Institute finds that agricultural R&D investment directly boosts total factor productivity: the more significant the investment, the greater the gains. Were the U.S. to commit to 7 percent annual growth in public investment over the coming decade, total factor productivity of global agriculture would increase 20 percent over baseline by 2050.
EXTREME WEATHER EVENTS AND PRODUCTIVITY GROWTH: NEW RESEARCH

By Wei Zhang, Assistant Professor, Applied and Agricultural Economics, Virginia Tech

Professor Zhang is the GAP Initiative Faculty Research Fellow. Funding for her research was provided by CALS Global in the College of Agriculture and Life Sciences at Virginia Tech.

Studies of climate change and agriculture tend to focus on a limited number of environmental or agricultural factors, reducing their usefulness in evaluating complex, system-level threats.

As a performance indicator of a country’s agriculture system, total factor productivity growth captures the overall impact of climate events.

Extreme climate events are estimated to have, on average, a negative and statistically significant impact on the TFP growth rate.

The estimated impact of droughts is more than three times the impact of an average extreme climate event.

Climate shocks can have a sustained impact on the growth trajectory of agricultural productivity well beyond the initial event.

Photo: ©2021 Alianza de Bioversity International y CIAT/Juan Pablo Marin Garcia
Climate change affects many dimensions of agricultural systems and could threaten global food security and social stability (Wheeler and Von Braun, 2013). However, studies have disproportionately focused on the effects of changes in average seasonal temperature and precipitation (see, e.g., Schlenker and Roberts, 2009; Lobell et al., 2011). However, it is increasingly evident that climate change has implications besides rising average temperature or precipitation.

The frequency and intensity of extreme weather events, such as severe droughts, intense storms, or scorching heat waves, have increased over the last few decades. Our research examines the relationship between extreme climate events and agricultural productivity growth across countries. It is hard to overemphasize the importance of enhancing agricultural productivity for poverty reduction and economic transformation (Johnston and Mellor, 1961; Christiaensen et al., 2011; Jayne et al., 2021). However, it is increasingly evident that climate change has implications besides rising average temperature or precipitation.

We use total factor productivity (TFP) to measure agricultural productivity. TFP is the ratio of aggregate output to aggregate input, including land, labor, capital, and other materials. The data on extreme climate events are from the International Disasters Database (EM-DAT). We include the following climate events in our study: storm, extreme temperature, flood, drought, and wildfire. Though there is no consensus on the classification of extreme climate events, this list includes most of the commonly considered weather and climate events.

When extreme climate events occur, many aspects of agricultural systems are influenced. The immediate outcome is the diminution of agricultural output (Lesk et al., 2016). In addition, regional resource reallocation could follow, such as the diversion of irrigation water or changes in transportation channels. The physical capital of agricultural production, such as machinery and livestock inventory, and the infrastructure of supply chains, such as roads or storage units, could also be negatively affected. The economic consequences often go beyond the impact area of an extreme climate event. Thus, extreme climate events could affect the entire agricultural sector or even a country’s economy. Agricultural TFP growth as a performance indicator of a country’s agriculture captures the overall impact of climate events.

Climate shocks can have a sustained impact on the growth trajectory of agricultural productivity. Dynamic effects are frequently long-lasting, representing the impacts of climate change on the adjustment path of agricultural systems. When climate shocks result in productive asset destruction, households, communities, and countries may have to save and reinvest to return to the capacity to produce at the level they had before the shock.

In general, one would expect the TFP growth rate to be lower than the trend on impact due to loss of outputs but could be either higher or lower than the trend thereafter. For example, if a drought leads to investment in irrigation systems or adopting drought-tolerant seed varieties, TFP growth could be faster than along the previous trajectory (Caballero et al., 1994). However, institutional constraints, such as lack of credit or access to markets, could affect the long-term impact of extreme climate events. Studies have shown that long-run impacts of extreme climate events are particularly damaging to the economic development of disaster-prone low-income countries (Carleton and Hsiang, 2016; Hallegatte and Rozenberg, 2017). Households and countries struggling to meet basic consumption requirements may have a tough time for reconstruction and asset accumulation, thus staying at a lower growth path or even trapped in a low-level equilibrium (Hallegatte et al., 2007).
We estimate that extreme climate events on average have a negative and statistically significant impact on the TFP growth rate. The estimate is not sensitive to controlling for changes in temperature and precipitation. To put the estimate in perspective, in a year when the total number of extreme climate events per 100 square km is at the sample mean of 1961-2016 (0.0022), TFP growth rate is estimated to be lowered by 0.46 percentage points. In 2016, Haiti experienced floods, storms, and drought, which put their total number of extreme climate events per 100 square km to be 0.029, at the 99th percentile of our measure of extreme climate events. Based on our estimate, their TFP growth rate would be lowered by six percentage points.

The estimated impacts on TFP growth rate are all negative across different extreme climate event types and are statistically significant for storms and droughts. The estimated impact of droughts is more than three times the impact of an average extreme climate event.

At the sample mean of our measure of drought (0.0015), the TFP growth rate would be lowered by 1.11 percentage points. Future analysis could examine the channels through which droughts could affect agricultural productivity growth more than storms or floods. One hypothesis is that droughts affect wider geographic areas than storms or floods. Though not precise, the estimated impact of wildfires on TFP growth is the largest among all types, about six times the impact of an average extreme climate event. One hypothesis is that wildfires damage the capital of agricultural production, such as perennial crops, more than other extreme climate events.

Our study provides an overall assessment of extreme climate events on agricultural productivity growth. Macro-econometric studies like ours do not capture their impact at the sub-national level (Damania et al., 2020). Future finer-scale studies could be insightful on the channels of adaptation of agricultural systems—both institutional and physical—to climate extremes.

Endnotes for this article are available at globalagriculturalproductivity.org. Explore the online map of the number of extreme weather events per 100 square km from 1961-2019. Correspondence for Wei Zhang may be sent to: wzb@vt.edu.
The current downward trajectory of agricultural productivity growth must be reversed. Climate change, conflict, and extreme weather events add multiple layers of difficulty and complexity to an already challenging task. Governments, the private sector, research institutions, international development organizations, and civil society groups need to work collaboratively to create an enabling environment for agricultural innovation, services, and knowledge to take root. In addition, small-scale producers must focus on urgent and vigorous action to accelerate productivity growth, improve food security, increase incomes, and strengthen sustainability and resilience.

The GAP Report’s six policy and investment priorities for productivity growth are data-driven solutions with proven results. Additional information is available at globalagriculturalproductivity.org.

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<th><strong>Policy and Investment Priorities</strong></th>
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<td>Invest in public agricultural R&amp;D and extension services</td>
<td>Public sector agricultural R&amp;D and extension services generate innovation and information that facilitate environmentally sustainable agricultural output growth, improve human health, and support a vibrant agricultural economy.</td>
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<td>Embrace science- and information-based technologies and practices</td>
<td>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.</td>
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<tr>
<td>Improve the infrastructure and market access for agricultural inputs and outputs</td>
<td>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.</td>
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<tr>
<td>Cultivate partnerships for sustainable agriculture and improved nutrition</td>
<td>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.</td>
</tr>
<tr>
<td>Expand and improve regional and global trade</td>
<td>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.</td>
</tr>
<tr>
<td>Reduce post-harvest loss and food waste</td>
<td>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.</td>
</tr>
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</table>
TFP Growth in East Africa reached its peak between 1991 and 2000. Since then, it has declined, reaching negative growth between 2011 and 2020. Irrigation extension has changed little over the past six decades, while input intensification growth has surged since 1991. Land expansion continues to be the primary driver of agricultural output growth; however, during the last decade, there has been a cooling off in the region’s output growth rate.

On June 23, 2022, the Global Agricultural Productivity Initiative at Virginia Tech held a multi-sectoral event in Nairobi, Kenya, to discuss the need and potential pathways for increasing agricultural productivity, especially among smallholder farmers, in East Africa. Leaders and experts from the public sector, industry, academia, research institutes, NGOs, and farmer organizations participated in panel discussions and an interactive workshop to discuss the way forward.

In his keynote address, Tim Njagi, Research Fellow at Egerton University’s Tegemeo Institute in Nairobi, emphasized that “for sustainable growth, Kenya and the region must rely on increasing productivity on available land.” He outlined the importance of investment in agricultural research and development given demonstrated success in addressing emergent challenges such as the adverse effects of climate change and weather variability, increased pest and disease outbreaks, lack of household resilience to production shocks, and limited value addition and agro-processing scalability.

“We have the potential. We have the people. We have the land. Africa can become a supplier of global food needs, which will contribute to resilient food and nutrition security on a global scale.”

— Dr. Canisius Kanangire, Executive Director, AATF
Three working groups convened in the collaborative workshop portion of the agenda to discuss urgent action items for accelerating productivity growth in Kenya. The key recommendations are summarized below.

**Key Technologies and Innovations for Accelerating Productivity Growth**

- Prioritize improved inputs.
- Technologies and innovations that consider the environmental contexts and constraints are imperative for adapting to climate change and reducing investment risk.

**Priorities for Improving Access to Finance, Markets and Information, Transportation, Storage, and ICT**

- The affordability of information and communication technology must be improved; digital literacy will rapidly follow.
- Partnerships between academia, scientists, and the private sector must be harnessed to reduce the cost and time it takes to reach scale.

**Barriers Preventing Smallholders from Accessing Productivity Enhancing Solutions**

- Affordability and availability of productivity-enhancing solutions
- Policies and policy setting environments

**Recommended Actions for Policymakers and Legislators to Create a More Robust Enabling Environment for Productivity Growth**

- Strengthen existing policies. This will require a review, evaluation, and participatory development process that includes county governments and other governance stakeholders.
- Create policies that are evidence-informed and data-driven. Policymakers are looking for trustworthy sources of data and evidence, accompanied by solid recommendations backed by science and demonstrated return on policy change.

**What Actions, Policies, and Investments, Can Be Taken in the Next 12 to 36 Months to Accelerate TFP Growth in the Region?**

- Achieve consensus on the critical evidence gaps, mobilize investment to fill them (not only financial but could include a commitment of partners to deploy through interventions and programming), and create partnerships in the enabling environment to scale proven innovations and solutions.
- Develop compelling regulatory and legal frameworks to ensure the implementation of existing policies and policy changes.

**What Would Change in East Africa if a Sustainable Rate of TFP Growth Could Be Achieved?**

- Livelihoods would be improved. Basic needs would be met.
- An economic multiplier effect would activate, leading to prosperity and regional resilience.

A full list of recommendations and endnotes for this article are available at globalagriculturalproductivity.org. Correspondence for Jessica Agnew may be sent to: jlagnew@vt.edu.
REFERENCES


Fuglie, K., & Steensland, A. (2022, January). Strengthening the climate for sustainable agricultural productivity growth [PowerPoint slides].


The Global Agricultural Productivity Report (GAP Report) draws on expertise from the private sector, international aid agencies, civil society organizations, conservation and nutrition groups, universities, and research institutions.

Supporting Partners provide financial support and offer perspectives on critical issues facing the world’s agricultural systems. Consultative Partners provide insights on areas essential for productivity growth: agricultural research and development and extension systems, natural resource management and conservation, human nutrition and animal health, community-led development, gender equity, trade, and climate change.

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