Productivity-led Pathways to Sustainable Agricultural Growth: Six Decades of Progress

Des voies vers une croissance agricole durable axées sur la productivité : six décennies de progrès

Produktivitätsorientierte Wege zu einem nachhaltigen landwirtschaftlichen Wachstum: Sechs Jahrzehnte Fortschritt

Jeremy Jelliffe, Keith Fuglie and Stephen Morgan

Over the past sixty years (1961–2020), world agriculture has undergone a vast transformation. Agricultural output has increased nearly four-fold while the population has grown 2.6 times, leading to a 53 per cent increase in agricultural output per capita. Real food prices have declined relative to the general price level, providing for more affordable and diverse diets. Most of the growth in agricultural production has been achieved by raising productivity rather than expanding resource use in the sector. By the 2010s, however, the pace of output and productivity growth in world agriculture was slowing, food prices had risen in real terms, the number of food insecure people increased, and pressure to expand the use of natural resources to produce food had intensified. This creates a scientific and policy challenge as to whether productivity growth will be sufficient to meet world food needs while ensuring environmental sustainability.

Agricultural production is moving to the Global South

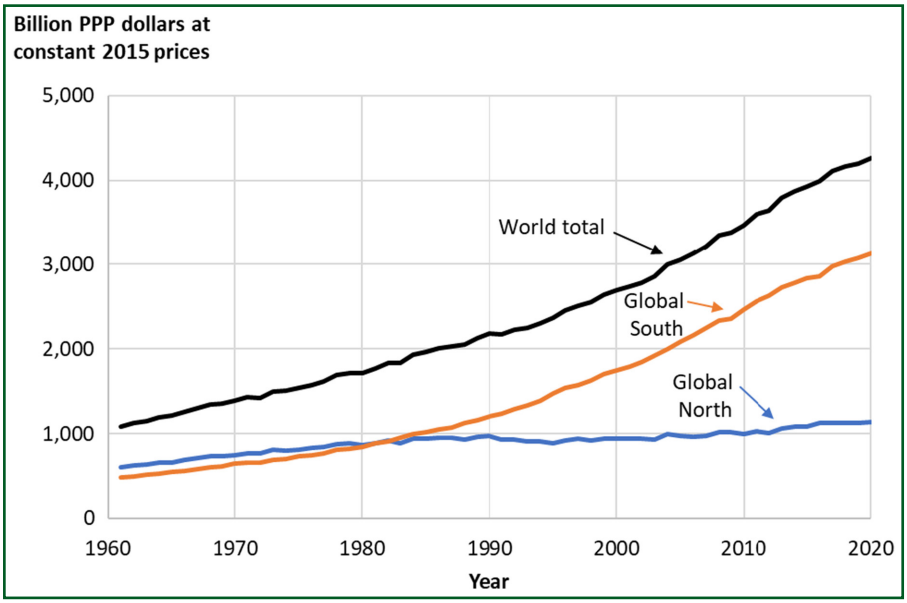
Over the last six decades, but especially since the 1980s, there has been a steady and pronounced shift in the location of agricultural production worldwide. Agricultural output in the Global South (consisting of Africa, Latin America and Asia except for high-income countries in East Asia), has steadily risen, while production in the Global North (Europe, Oceania, high-income East Asia, Canada and the United States) has remained roughly constant since the 1980s, measured in purchasing power parity (PPP) real dollars (Figure 1). As a result, the share of world agricultural output produced in the Global South between 1961 and 2020 increased from 44 per cent to 73 per cent, while the share of production in the Global North declined from 56 per cent to 27 per cent.

In addition to this location shift, the commodity composition of world agriculture evolved over these decades to include a larger share of output in oil crops, non-ruminant livestock products (poultry and pigs), and aquaculture. By 2020, farmed fish and other products from aquaculture accounted for 7 per cent of the value of global agricultural output, an increase from less than 1 per cent in the 1960s and 1970s. At the same time, the share of world output consisting of root and tuber crops and cereal grains declined.

New inputs replacing land and labour

Major technological developments in farming over the last 60 years included the spread of Green Revolution crop

Figure 1: World agricultural production shifts from the Global North to the Global South



Note: The Global South consists of Africa, Latin America and the Caribbean, and Asia except high-income countries of East Asia. The Global North consists of Canada-United States, Europe, Oceania, and high-income countries of East Asia.

Source: Fuglie *et al.* (2024).

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genetic improvements, the development of biotechnology and genetically modified crops offering pest and disease resistance, advances in animal and aquaculture genetics, health and husbandry practices, and improvements in farm mechanisation and automation. The use of manufactured inputs like synthetic fertilisers, agricultural chemicals, animal feed concentrates, and farm machinery greatly expanded. The share of cropland that is irrigated also increased.

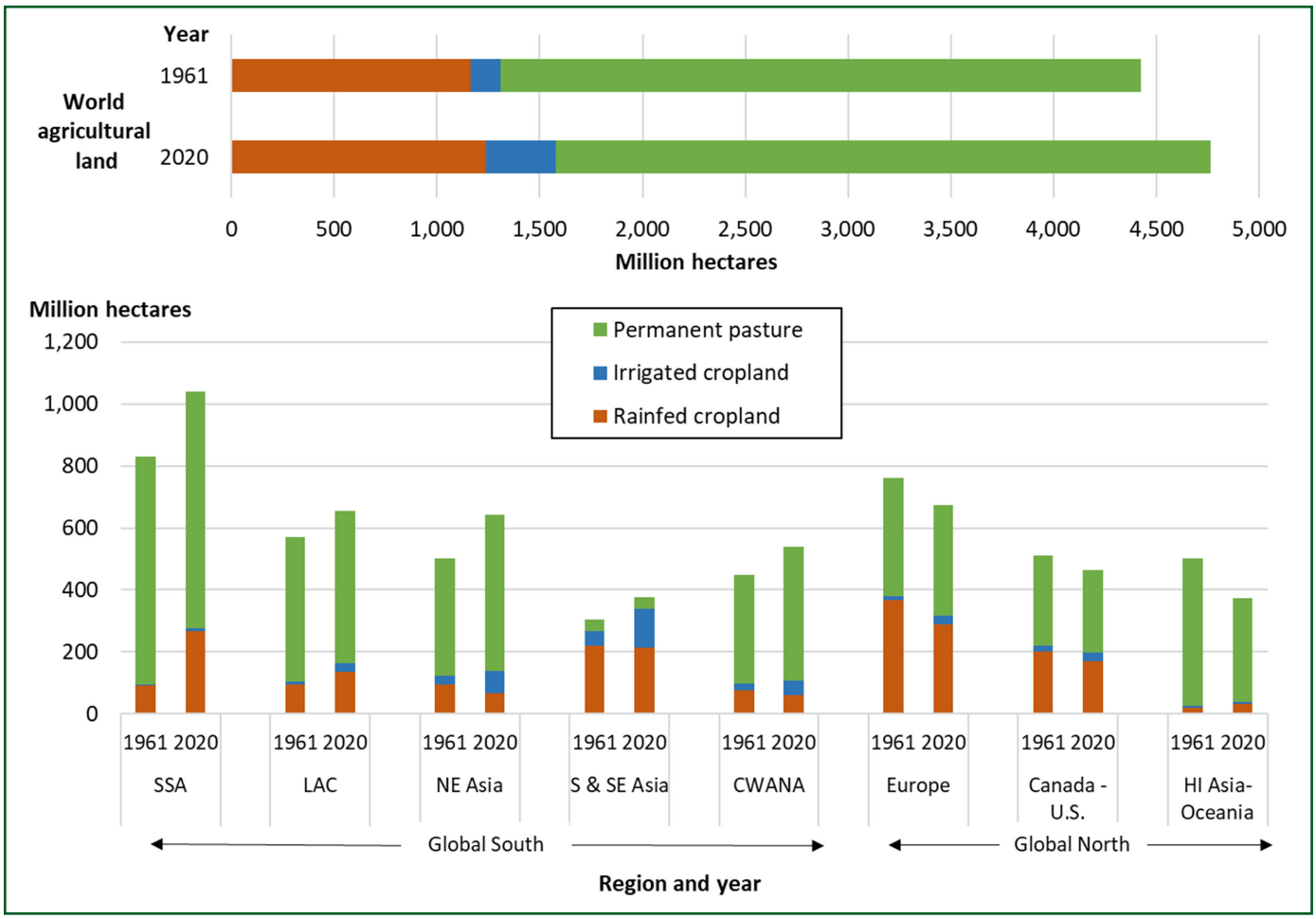
Between 1961 and 2020, agricultural land area world-wide increased by 7.6 per cent to 4.76 billion hectares, or 32 per cent of the world's land area. Agricultural land expanded in the Global South by 596 million hectares while contracting in the Global North by 260 million hectares, resulting in a net global increase of 336 million hectares (Figure 2). In addition, land quality improvements were made by converting pastures to cropland and by extending irrigation onto cropland. Total irrigated area increased from 147 million hectares to 343 million hectares over 1961–2020. By 2020, about 21 per cent of global cropland was equipped for irrigation.

> "Die wichtigste Triebkraft für das weltweite Wachstum der landwirtschaftlichen TFP waren die öffentlichen und privaten Investitionen in Forschung und Entwicklung."

In terms of agricultural labour, the total number of people working on farms peaked in 2003 at just over 1 billion and then declined to 841 million by 2020, working on approximately 600 million farms. The decline in labour use observed since the early 2000s illustrates the substitution of capital for labour at the global scale and patterns of capital accumulation in agriculture (Figure 3). For many farms, the average number of workers has remained constant at 1 to 2 workers per farm while the size of operations has grown. Improvements in machinery and equipment like tractors and various accessories have reduced the number of hands needed to complete a task, such as pre-planting land preparation, seeding, spraying and harvesting.

At the same time, these advancements have coincided with the expanded use of fertiliser and chemical inputs in

Figure 2: Land in agriculture is rising in the Global South and falling in the Global North



Note: SSA = Sub-Saharan Africa; LAC = Latin America and the Caribbean; CWANA = Central & West Asia and North Africa; United States (U.S.); HI Asia-Oceania includes Japan, Korea, Taiwan, Australia, and New Zealand.
Source: Fuglie *et al.* (2024).

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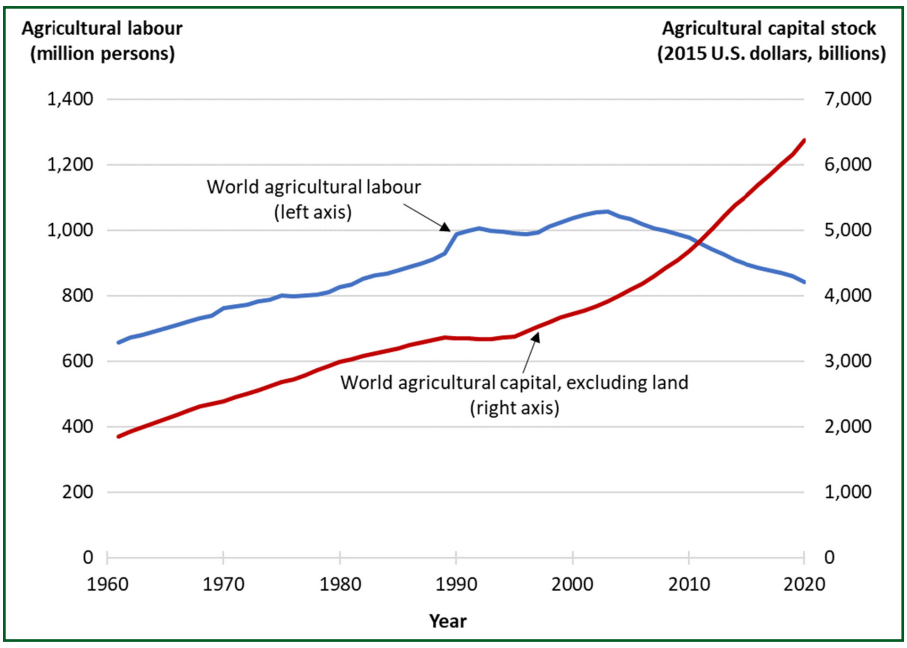
crop production and animal feed concentrates and veterinary pharmaceuticals in animal production. The use of inorganic nitrogen fertilisers grew especially rapidly, from around 12 million metric tons in 1961 to 112 million metric tons in 2020. For animal feed, about one-third of world production of cereal grains is fed to livestock. Over time, animal feeds have shifted to include more nutrient-dense diets, especially protein. The increased use of proteins in animal feeds has greatly expanded global demand for oilseeds. When oilseeds are crushed to extract vegetable oils, the left-over protein-rich meals provide an important component of animal feed concentrates.

Figure 3: Labour is being replaced by capital



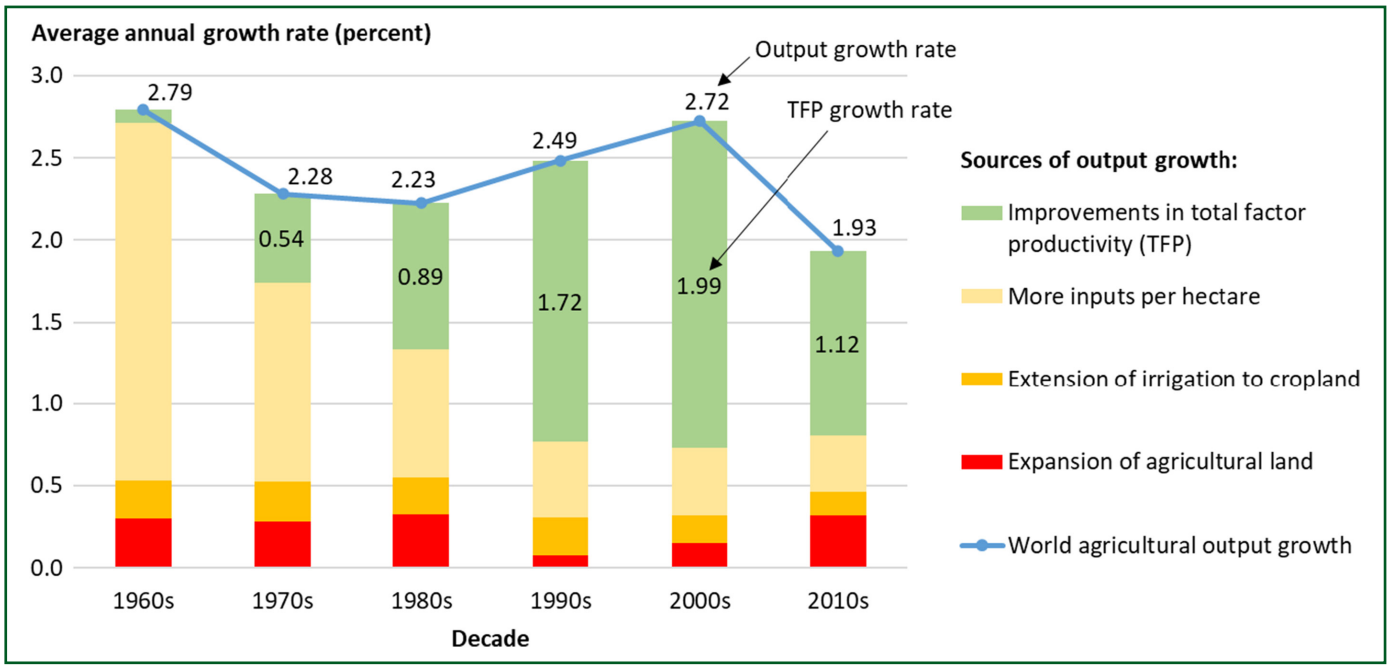
Source: Fuglie *et al.* (2024).

Productivity has become the dominant growth vector

Figure 4 shows changes in agricultural output growth by decade while also decomposing output growth into four different components: the expansion of agricultural land area, which includes cropland and pasture; the extension of irrigation to cropland which improves land quality; more intensive use of all other inputs including labour, capital and materials per unit of land; and improvements in total factor productivity (TFP). TFP is a broad measure of productivity which reflects the overall efficiency with which farmers use agricultural inputs (land, labour, capital, etc.) to produce crop and animal outputs (see Box 1). While conventional measures of partial productivity focus on the ratio of a single input to output (e.g. crop yield per hectare or value-added per worker), TFP is a measure of the efficiency with which multiple inputs are transformed into agricultural output.

Over time, agricultural output growth shifted from resource-dependent to productivity-led growth (Fuglie, 2015). From the 1960s to the 1980s, agricultural output growth was driven primarily

Figure 4: Sources of growth in world agricultural output by decade over 1961–2020



Note: Total factor productivity (TFP) is the ratio of total commodity output to the total land, labour, capital and material inputs employed in production; TFP growth rate for 1960s (not displayed) is 0.08 per cent.
Source: Fuglie *et al.* (2024).

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A misty morning sunrise in strawberry garden at Doi Angkhang mountain © sripfoto – stock.adobe.com.

by using more resources in agricultural production including land expansion, irrigation, and especially intensification of other inputs per hectare of agricultural land. However, since the 1990s increases in TFP have accounted for most of the agricultural output growth. This shift has been driven by several factors including the adoption and spread of improved technology and farming practices over much of the globe.

Between 1961 and 2020, global agricultural output grew at an average annual rate of 2.3 per cent. However, during the most recent decade agricultural output growth slowed. From 2011 to 2020, agricultural output grew at 1.93 per cent annually compared with 2.72 per cent from 2001 to 2010. Most of the slowdown in agricultural output growth can be attributed to a decline in TFP growth. Between 2001–2010 and 2011–2020, annual TFP growth fell by nearly half, from 1.99 per cent to 1.12 per cent. While the rate of land expansion, though still a relatively small part of agricultural growth, increased significantly in 2011–2020 compared with the previous two decades.

Several factors may be contributing to the slowdown in TFP growth. Decreasing investment in public agricultural R&D in some countries may provide fewer new productivity-enhancing innovations (Alston *et al.* 2010; Fuglie, 2018; Heise and Fuglie, 2018; Moreddu and Van

Box 1. The USDA-ERS data product on international agricultural productivity

The USDA-ERS International Agricultural Productivity data product publishes annual indices of agricultural total factor productivity (TFP) for 179 countries and territories, as well as regional and global aggregates. This data product was first published in 2013 and is updated annually. Findings in this article use the October 2022 version of the data product which contains data from 1961 to 2020.

To measure the rate of TFP growth, USDA-ERS first calculates the rates of growth in total agricultural outputs and total agricultural inputs. The rate of growth in TFP is measured as the difference between the total output and total input growth rates. If output is growing faster than inputs, it means the same amount of output is being produced with fewer inputs or that TFP is increasing.

Agricultural output is the aggregation of 200 agricultural commodities, including 162 crops, 30 animal products, and 8 aquaculture products. Country-level output quantities of crop and livestock commodities for each country are from FAOSTAT while quantities of aquaculture products are from FISHSTAT. Commodity production is aggregated using fixed weights representing global average commodity prices from 2014–2016.

Agricultural inputs are the amounts of land, labour, capital and intermediate inputs which include agricultural fertilisers and chemicals, seeds, feeds, animal health products, fuel and electricity employed in production. The primary sources of input data are FAOSTAT for agricultural land, capital and fertiliser; ILOSTAT for agricultural labour; while animal feed quantities are derived from the commodity balance sheets in FAOSTAT and the USDA Foreign Agricultural Service's Production, Supply and Distribution (PS&D) database.

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Tongeren, 2013). At the same time, farmers in some parts of the world may be affected by weak agricultural extension systems, restricted access to some new production technologies, barriers to trade, or regional conflicts. New and emerging crop and animal diseases and pests as well as climate change and associated severe weather events may have reduced crop yields in some areas (Ray *et al.*, 2019). Using international agricultural productivity data from USDA's Economic Research Service (USDA-ERS), Ortiz-Bobea *et al.* (2021) estimated that between 1961 and 2015, anthropogenic climate change reduced global agricultural TFP growth by about one-fifth (21 per cent), equivalent to losing the last 7 years of productivity growth. This serves to reaffirm the critical role of innovation and productivity in mitigating the effects of climate change on global food supply (e.g. Salois, 2015).

Europe vs. North America: sustainable paths diverge

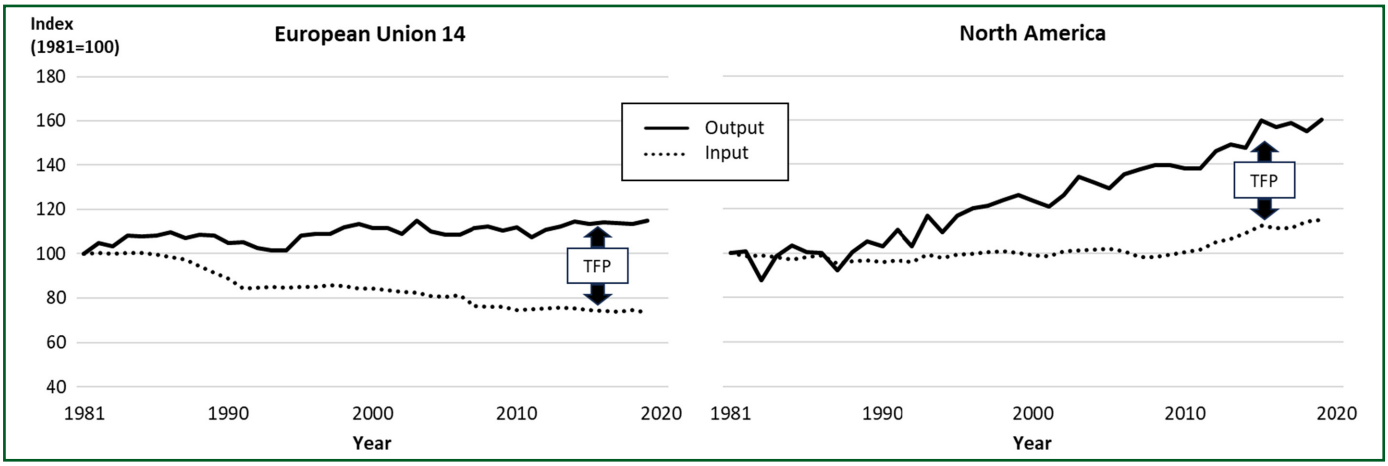
In the Global North, the contrasting agricultural trajectories of the European Union (focusing on the EU14[1] for consistency over time) and North America (Canada-United States) over 1981–2020 illustrate the different ways that productivity can contribute to sustainable growth, which conceptually we view as growth that does not depend on increased natural or environmental resource use, including undesirable byproducts such as greenhouse gas emissions. Both regions achieved nearly identical rates of agricultural TFP growth over this 40-year period (1.07 and 1.09 per cent per year in North America and the EU14, respectively). In North America, productivity growth expanded output, while in the EU14 productivity growth led to significant reduction in the total resources employed in the agricultural sector. Even though both regions produced roughly the same level of gross agricultural output in the 1980s, by 2020, North America generated about 50 per cent more agricultural product than the EU14. However, over this period the EU14 reduced total inputs employed in agriculture by over one-fourth, while in North America, total input use increased by about 15 per cent (Figure 5).

From the perspective of sustainability, TFP growth has meant agricultural input use in food, fibre and fuel production has steadily declined in absolute and relative terms for the EU14 and North America, respectively. Understanding the policies and market conditions that supported TFP growth in these regions, albeit in different ways, can offer insights into pathways for a sustainable future.

The key driver of agricultural TFP growth around the world has been public and private investment in research and development (R&D). A review of more than 40 studies of long-term agricultural TFP growth in each world region found that public R&D spending accounted for half or more of that growth (Fuglie, 2018). Since agricultural technologies and practices are sensitive to climate, soil and social conditions, they often need to be developed and adapted locally. Thus, most countries have invested in national agricultural R&D systems, and overall, the total world spending on public agricultural R&D (in inflation-adjusted dollars) increased by 76 per cent between 1991 and 2016. For the Global North, data from 2016 showed that Western European countries spent US$ 7.2 billion and Canada-United States spent US$ 5.5 billion in public agricultural R&D (in 2015 PPP$), or US$ 1,276 and US$ 2,388 per farm, respectively.

> “Le principal moteur de la croissance de la PTF agricole dans le monde a été l'investissement public et privé dans la recherche et le développement (R&D).”

Figure 5: Europe and North America experienced similar rates of agricultural productivity growth while trends for input use and output differed between the regions, 1981–2020



Note: European Union 14 (EU14) includes Austria, Belgium, Denmark, Finland, France, Germany (both East and West, pre-1990), Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, and Sweden; United Kingdom is excluded from the EU14; North America includes Canada and the United States.

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But why did TFP growth result in output expansion in North America and input reduction in the EU14? One likely explanation is that policy reforms enacted in the 1990s and in subsequent years, together with market forces, pushed each region in the direction of greater production efficiency. Following World War 2, both North American and European governments intervened in agricultural markets to support farm income and promote production. In both regions, agricultural policy interventions led to farm surpluses and costly surplus management policies (Johnson, 1973). Policy reforms in the 1990s partially 'decoupled' subsidies from production, providing direct income support to producers instead of production-based payments, particularly in the EU. This served to reduce market distortions caused by agricultural policies (OECD, 2017). Between 1986–1988 and 2020, the share of total farm subsidies that was tied to commodity output in the Global North as represented by OECD membership, fell from 81 per cent to 39 per cent (OECD, 2022).

The EU single market and Common Agricultural Policy (CAP) are touchstones of the continental market and policy landscape. As the EU and its single market grew through multiple waves of expansion, market forces and policy shaped how and where agriculture took place on the continent. Reforms since the 1990s have pushed EU prices closer to world prices. This marked the beginning of a period of stable output and input reduction that has occurred in EU agriculture. Resulting lower commodities prices encouraged the exit of resources from the EU farm sector. The common EU labour market also facilitated transfer of workers from agriculture to other sectors. Further CAP reform created a two-pillar system that offered alternative support payments to landowners to further reduce inputs and conserve natural resources. Market forces along with CAP reform released marginal lands, ones that are less suitable to farming or sensitive ecological areas (e.g. habitats or proximity to freshwater bodies), from agricultural production allowing for greater efficiency in the use of resources. On the other side of the Atlantic, the United States eliminated acreage set aside, while labour movement out of agriculture had advanced further than in the EU and an internationally competitive agricultural sector encouraged exports to grow.

Productivity preserves natural resources and environment

One dimension of productivity growth is that it has saved land from conversion to agricultural uses. Between 1990 and 2020, the amount of cropland needed to produce a common basket of US$ 1,000 of crop commodities declined by nearly half, from 1.1 hectares to 0.6 hectares (and down from 1.9 hectares in 1961). The amount of irrigation water applied to obtain US$ 1,000 of crop output was also reduced, from 1.8 megaliters in 1991–1995 to 1.1 megaliters in 2016–2020 (Figure 6). These gains in resource efficiencies are due to a combination of factors, including adoption of improved technologies and practices, specialisation, and concentration of production in the most agriculturally favorable environments. In some countries, the use of irrigation water has shifted to more high-value crops and less arid areas, which also contributes to a rising average value of output per volume of irrigation water applied.

Achieving higher output per unit of land and irrigation water may also involve more intensive use of other inputs, like labour, capital and

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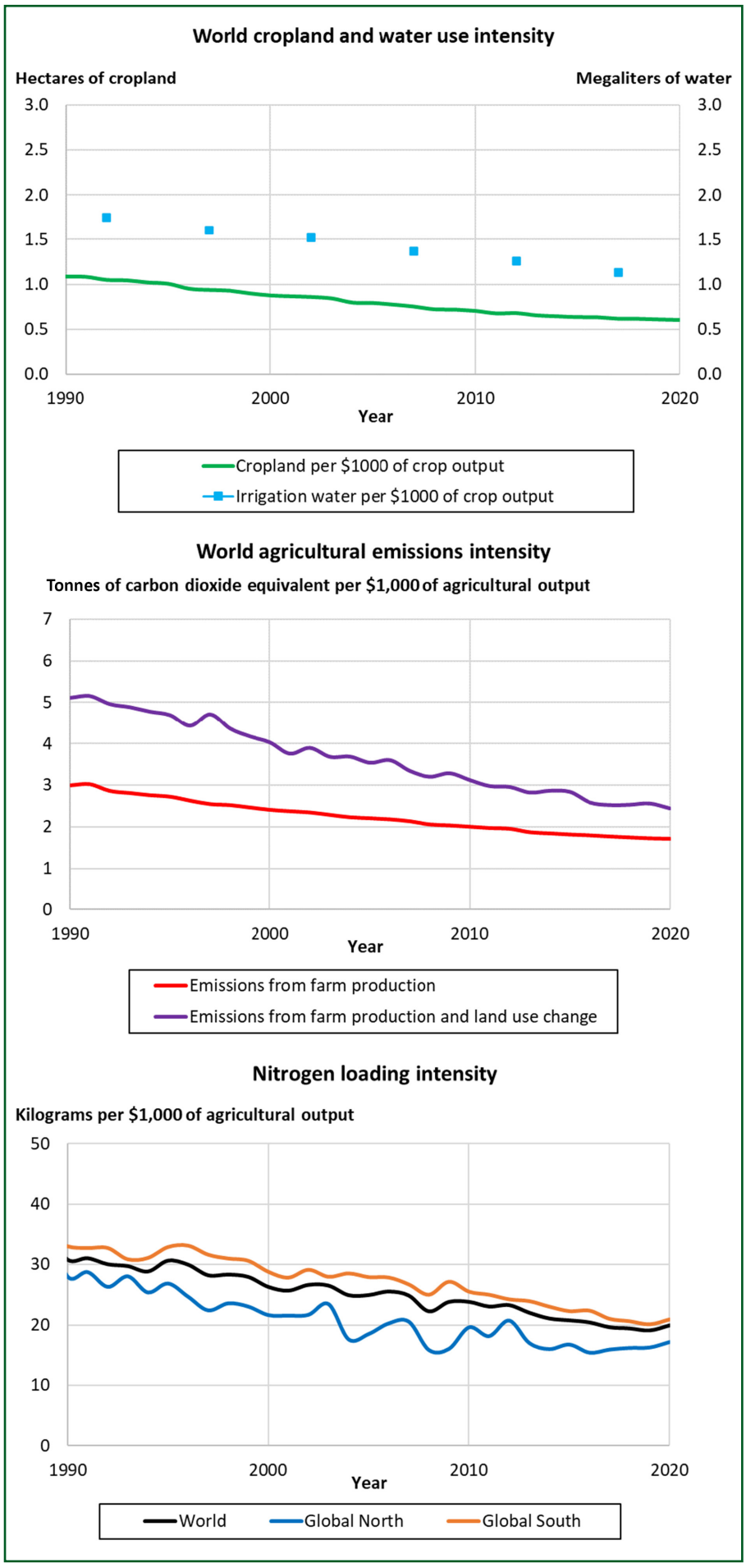
fertilisers, per hectare of agricultural land. If not carefully managed, input intensification could degrade natural resources, increase the risk of excess nutrient runoff into water bodies, raise greenhouse gas emissions from agriculture, and cause the loss of biodiversity, for example.

However, the gradual transition to TFP-led growth in world agriculture since the 1960s (and especially since the 1990s) has resulted in reduced resource-use intensity (resource used per constant volume of output) for other environmental resources in addition to land and irrigation water. Between 1990 and 2020, greenhouse gas (GHG) emissions from agriculture (including agricultural land use change) per US$ 1,000 of agricultural output fell by more than half, from 5.1 tonnes to 2.5 tonnes of CO_2-equivalents (Figure 6). CO_2-equivalents aggregate the combined effect of carbon dioxide (CO_2), methane, nitrous oxide and other GHG emissions that cause global warming. GHG emissions from agriculture arise from both farm production (such as methane from livestock and rice paddies and nitrous oxide from fertiliser use) and land use change, which results in the one-time release of large carbon stocks in forests and soils when converted to cultivation of crops. Average agricultural GHG emissions intensity has declined due to both lower rates of land use conversion and to improved farm production efficiency. An earlier *EuroChoices* infographic by Guerrero and Nakagawa (2019) provided an extensive representation of the apparent productivity-emissions tradeoff in agriculture.

At the global level, nutrient loadings (the difference between total nutrients applied to cropland from fertilisation, manure, biological nitrogen fixation and rainfall, and the amount of nutrients removed from the field in the crop harvest) per volume of agricultural output have also fallen sharply. For nitrogen, nutrient loadings per US$ 1,000 of crop output declined from 31 kg to 20 kg between 1990 and 2020 (Figure 6). Phosphate

Figure 6: Higher agricultural productivity leads to fewer natural and environmental resources per unit of agricultural output, 1990–2020



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loading intensity has declined by an even greater proportion over this period.

> "The key driver of agricultural TFP growth around the world has been public and private investment in research and development (R&D)."

Returning to our EU14–North America comparison, similar trends are observed in resource-use intensities in each region. Over 1990–2020, both regions had very similar levels (and achieved similar reductions) in GHG emissions per unit of output and nitrogen loading per unit of output. The fact that productivity growth reduced overall input use in the EU14 meant that total GHG emissions and nitrogen loadings declined, while in North America they remained roughly constant even as output increased.

It is important to highlight that there are variations in agricultural resource use intensities by region that persist, especially between the Global North and Global South. From 2016–2020, the Global North had relatively higher use intensities for total agricultural land and cropland (due to less intensive cropping systems in the Global North) while the Global South had higher average use intensities for irrigation water, excess nitrogen and phosphorous loadings, and GHG emissions. But there are also large variations across Global South regions: the lowest GHG emissions intensity over this period was achieved in Northeast Asian countries, while the highest emissions intensity was in Sub-Saharan Africa (SSA) which was still converting significant land area to agricultural production. Conversely, SSA had the lowest nutrient loading intensities of any region due to low levels of synthetic fertiliser use. These current differences highlight long-run changes in the intensity of environmental resource use as agriculture has moved from the Global North to the Global South.

Conclusions

The close association between agricultural TFP growth and improved economic and environmental performance suggests that TFP-led growth can be leveraged for sustainable and resilient agricultural intensification. Between 1990 and 2020, the amount of cropland used and the GHGs emitted for a given volume of agricultural output fell by half, irrigation water intensity fell by nearly 40 per cent, and nitrogen loading intensity fell by 35 per cent. Growth in agricultural TFP has contributed to a decoupling of agricultural growth from the use of natural and environmental resources.

At the global level, however, improvements in agricultural TFP have not been sufficiently rapid or universal to make a significant dent in the total impact of agriculture on the environment. This is especially true in the Global South, where TFP growth slowed from an average rate of 2.2 per cent annually from 2001–2010 to 1.1 per cent in 2011–2020 (which accounts for most of the slowdown in world agricultural TFP growth over this period). Several factors may be affecting the global slowdown in productivity growth (Fuglie *et al.*, 2021). Climate change, causing increased frequency of adverse weather shocks, can

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negatively affect yields. Additionally, the emergence of new crop diseases and pests, slow diffusion of improved agricultural technologies, and reduced public agricultural R&D expenditures may be associated with lower TFP growth. Furthermore, barriers to market access including both tariff and non-tariff barriers to trade may slow technology transfer and reduce producer incentives to specialise. Overall, this slowdown in productivity growth has significant implications for global food security and environmental resource conservation. A prolonged slowdown or stagnation in agricultural TFP will make food scarcer and more expensive, encourage expansion of agriculture into more natural lands, and make it increasingly difficult to achieve global aspirations for a food secure and environmentally sustainable world.

Note

1 European Union fourteen (EU14) includes Austria, Belgium, Denmark, Finland, France, Germany (both East and West, pre-1990), Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain and Sweden; United Kingdom is excluded from the EU14.

Acknowledgements

This article is drawn from *World Agricultural Production, Resource Use, and Productivity, 1961–2020* by Keith O. Fuglie, Stephen Morgan and Jeremy Jelliffe, USDA-ERS Economic Information Bulletin 268, 2024. Readers may also be interested in Economic Research Service (2023). *International Agricultural Productivity*, USDA-ERS data product. US Department of Agriculture (October 2023 update).

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The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or US Government determination or policy.

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Summary

Productivity-led Pathways to Sustainable Agricultural Growth: Six Decades of Progress

In recent decades, world agriculture has undergone a vast transformation. Between 1961 and 2020, global agricultural output increased nearly four-fold while population grew 2.6 times, leading to a 53 per cent increase in output per capita. Real food prices declined, providing for more affordable and diverse diets. There was a pronounced and sustained shift in the location of production to the Global South (developing countries), which increased its share of global agricultural output from 44 to 73 per cent. Since the 1990s, increases in agricultural total factor productivity (TFP) has become the major driver of world agricultural output. However, insufficient productivity growth relative to demand has drawn more resources into agriculture. Globally, agricultural land area expanded 7.6 per cent between 1961 and 2020, although it contracted in the Global North (developed countries). In the EU, where agricultural output has remained relatively flat in recent decades, improvements in productivity reduced total inputs and environmental resources used by the sector. In contrast, in Canada-United States, productivity growth enabled agricultural output to expand without increasing total inputs and environment resources. By the decade of the 2010s, however, the pace of output and productivity growth in world agriculture slowed, real food prices rose, the number of food insecure people increased, and pressure to expand the use of natural and environmental resources to produce food intensified.

Des voies vers une croissance agricole durable axées sur la productivité : six décennies de progrès

Au cours des dernières décennies, l'agriculture mondiale a connu une vaste transformation. Entre 1961 et 2020, la production agricole mondiale a été multipliée par quatre tandis que la population a été multipliée par 2.6, ce qui a entraîné une augmentation de 53 pour cent de la production par habitant. Les prix réels des denrées alimentaires ont baissé, permettant ainsi des régimes alimentaires plus abordables et plus diversifiés. Il y a eu un déplacement prononcé et soutenu de la localisation de la production vers les pays du Sud (pays en développement), qui ont augmenté leur part dans la production agricole mondiale de 44 à 73 pour cent. Depuis les années 1990, l'augmentation de la productivité totale des facteurs (PTF) agricole est devenue le principal moteur de la production agricole mondiale. Toutefois, l'insuffisance de la croissance de la productivité par rapport à la demande a attiré davantage de ressources vers l'agriculture. À l'échelle mondiale, la superficie des terres agricoles a augmenté de 7.6 pour cent entre 1961 et 2020, bien qu'elle se soit contractée dans le Nord (pays développés). Dans l'Union européenne où la production agricole est restée relativement stable au cours des dernières décennies, les améliorations de la productivité ont réduit le total des intrants et des ressources environnementales utilisées par le secteur. En revanche, au Canada et aux États-Unis, la croissance de la productivité a permis à la production agricole de croître sans hausse de l'utilisation du total des intrants et des ressources environnementales. Cependant, au cours de la décennie 2010, le rythme de croissance de la production et de la productivité de l'agriculture mondiale a ralenti, les prix réels des denrées alimentaires ont augmenté, le nombre de personnes en situation d'insécurité alimentaire s'est élevé et la pression en faveur d'une utilisation accrue des ressources naturelles et environnementales pour produire de la nourriture s'est intensifiée.

Produktivitätsorientierte Wege zu einem nachhaltigen landwirtschaftlichen Wachstum: Sechs Jahrzehnte Fortschritt

In den letzten Jahrzehnten hat die Landwirtschaft weltweit einen umfassenden Wandel vollzogen. Zwischen 1961 und 2020 hat sich die globale landwirtschaftliche Produktion fast vervierfacht, während die Bevölkerung um das 2.6-fache wuchs. Die Pro-Kopf-Produktion ist dadurch um 53 Prozent angestiegen. Die realen Lebensmittelpreise gingen zurück, was zu einer preiswerteren und vielfältigeren Ernährung führte. Es kam zu einer ausgeprägten und anhaltenden Verlagerung der Produktion in den Globalen Süden (Entwicklungsländer), der seinen Anteil an der weltweiten landwirtschaftlichen Produktion von 44 auf 73 Prozent erhöhte. Seit den 1990er Jahren ist der Anstieg der totalen Faktorproduktivität (TFP) in der Landwirtschaft zur wichtigsten Triebkraft der weltweiten Agrarproduktion geworden. Das im Verhältnis zur Nachfrage unzureichende Produktivitätswachstum fordert jedoch mehr Ressourcen in der Landwirtschaft. Weltweit nahm die landwirtschaftliche Nutzfläche zwischen 1961 und 2020 um 7.6 Prozent zu, obwohl sie im globalen Norden (entwickelte Länder) schrumpfte. In der EU ist die landwirtschaftliche Produktion in den letzten Jahrzehnten relativ konstant geblieben, allerdings führten hier, Produktivitätssteigerungen zu einer Verringerung des Gesamtinputs und der vom Sektor genutzten Umweltressourcen. Im Gegensatz dazu ermöglichte das Produktivitätswachstum in Kanada und den Vereinigten Staaten eine Ausweitung der landwirtschaftlichen Produktion, ohne dass der Gesamtinput und die Umweltressourcen zunahmen. In den 2010er Jahren verlangsamte sich jedoch das Produktions- und Produktivitätswachstum in der globalen Landwirtschaft und die realen Lebensmittelpreise stiegen. Gleichzeitig nahm die Zahl der von Ernährungsunsicherheit betroffenen Menschen zu und damit auch der Druck, die Nutzung natürlicher und ökologischer Ressourcen zur Nahrungsmittelproduktion auszuweiten.

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