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What do we know about THE FUTURE OF WHEAT?

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Key messages

- Wheat has been and will remain a major component of diets globally. It accounts for an average of 18 percent of total energy intake and 19 percent of total protein intake globally. It is the primary staple food for 1.5 billion resource-constrained people in the Global South.
- Wheat represents 29 percent of the global cereals area and 14 percent of the global cropland area. It is an important crop in most agricultural areas of the world except the humid tropics and is less prominent in sub-Saharan Africa. Compared to rice and maize, it is more drought- and cold-tolerant.
- Wheat will continue to be an important source of protein in 2050, even under changing diets. In meat-based diets, wheat is often part of animal feed. In plant-based diets, wheat is a source of protein.
- Climate change offers both challenges and opportunities for wheat. Areas previously unsuitable for wheat production may have a comparative advantage under climate change. Similarly, some traditional wheat-growing areas may become less suitable for wheat production under climate change, especially due to heat stress. While Jägermeyr et al. (2021) indicate it can be beneficial for many existing wheat-growing areas, the impacts, for example, of increased frequency and intensity of heat waves, warmer night temperatures, and other weather anomalies are likely to counteract some of the benefits.
- Some of the poorer regions of the world are historically considered to be wheat-deficit areas and will increasingly depend on imports. This is a key factor in Africa, where there is less wheat production and wheat consumption is increasing with rising incomes.

RECENT TRENDS AND CHALLENGES

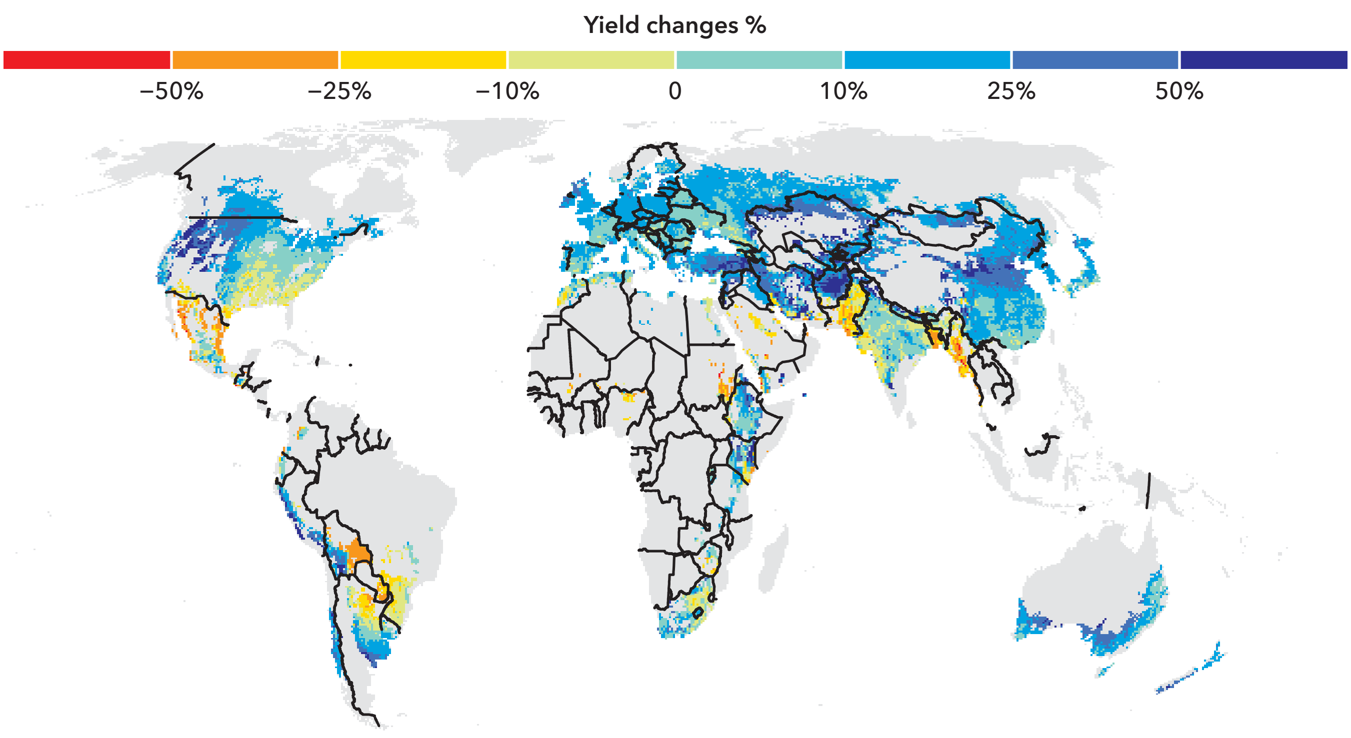
The growing human population and a changing environment have raised significant concern for global food security (Romanello et al. 2021). Economic development and urbanization induce changes in diets, leading to accelerated demand for some crops such as wheat in some geographies, while leading to stagnating demand in others. Economic development, urbanization, and related migration also lead to rural transformation (Kruseman et al. 2020), with impacts on crop and technology choices in wheat-based agrifood systems. Unexpected events, often called "black swan events (Bentley 2022; Mottaleb, Kruseman, and Snapp 2022; Noia Junio et al. 2022) and crises exacerbate these trends. Wheat is the most widely grown food crop in terms of area, representing 29.8 percent of the total cereal-growing area, with 779 metric tons (MT) produced globally in 2022 on 219 million hectares (ha); it is also among the fastest-growing crops in terms of cultivated area (especially in sub-Saharan Africa).

Climate change significantly impacts wheat production, particularly in low- and lower-middle income countries, where rising temperatures and disease pressures reduce yields and quality (Pequeno et al. 2021; Zhao et al. 2017; Asseng et al. 2019). Currently, wheat accounts for almost one-third of cultivated cereal land and about one-eighth of total cropland.

LATEST FORESIGHT RESEARCH

Foresight research on wheat and wheat-based systems often has a distinct focus. For example, a large body of work looks at the biophysical aspects of wheat production, especially in the context of climate change and climate change-induced stressors (Jägermeyr et al. 2021; Pequeno et al. 2021) (Figure 1). The analysis by Jägermeyr et al. may be overly optimistic being based on long-term averages, particularly for the more northerly latitudes, where extreme weather anomalies have already occurred in recent years and adversely affected wheat yields.

FIGURE 1 Projected global yield changes for wheat under RCP 8.5 for the end of the century in the absence of adaptation, technology change, and market adjustments



Source: Authors based on underlying data from Jägermeyr et al. (2021).

A second line of foresight research looks at the societal (social, economic, political, institutional, and policy) aspects of the future of wheat. In most cases, scenarios developed in other scientific domains are used as underlying assumptions. Few studies look at the interactions and feedback mechanisms between the biophysical and socioeconomic domains.

The traditional improvement rate of several important crops such as wheat seems inadequate to meet future demand (Ray et al. 2013) (see the case of Africa in Silva et al. 2023), reaching only 38 percent of the needed 60 percent for wheat by 2050. Technological breakthroughs in plant breeding such as speed breeding are expected to enhance wheat genetic gains (Li et al. 2018; Watson et al. 2018). Breeding strategies must continue to improve upon yield-advancing physiological traits, regardless of climate change impacts (Guarin et al. 2022; Frija et al. 2021). When including the second-order general equilibrium effects calculated with global economic models such as International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), Modular Applied GeNeral Equilibrium Tool (MAGNET), Model of Agricultural Production and its Impact on the Environment (MagPIE), or Global Biosphere Management Model (GLOBIOM), this discrepancy is overcome because both producers and consumers will respond to changed prices associated with new market equilibria (Chaudhary and Hertel 2024; Rosegrant et al. 2024; van Meijl et al. 2024).

Many studies overlook the role of management practices and varietal differences in adapting to climate change (Gbegbelegbe et al. 2017; Frija et al. 2021). Adapting wheat production to climate change involves implementing climate-smart agriculture (CSA) practices (Bhatt et al. 2016; Jat et al. 2019) and breeding climate-resilient varieties (Mondal et al. 2020). Compared to rice and maize, wheat is better adapted to frost and water deficit stress, both of which are expected to worsen with climate change.

To meet future demand under adverse conditions, such as declining groundwater in the Indo-Gangetic Plains, CSA solutions like subsurface drip fertigation in rice-wheat systems have shown promise, reducing nitrogen use by 20 percent and irrigation water by 50 percent without yield loss (Sidhu et al. 2019). Wheat also thrives in diverse climates, from high daytime temperatures in Sudan and Egypt to moderately warm, humid winters in Bangladesh and Brazil. Notably, Brazil is expanding wheat production in the Cerrado region, albeit with environmental impacts through drought-tolerant varieties, aiming for self-sufficiency (Noia Junio et al. 2024).

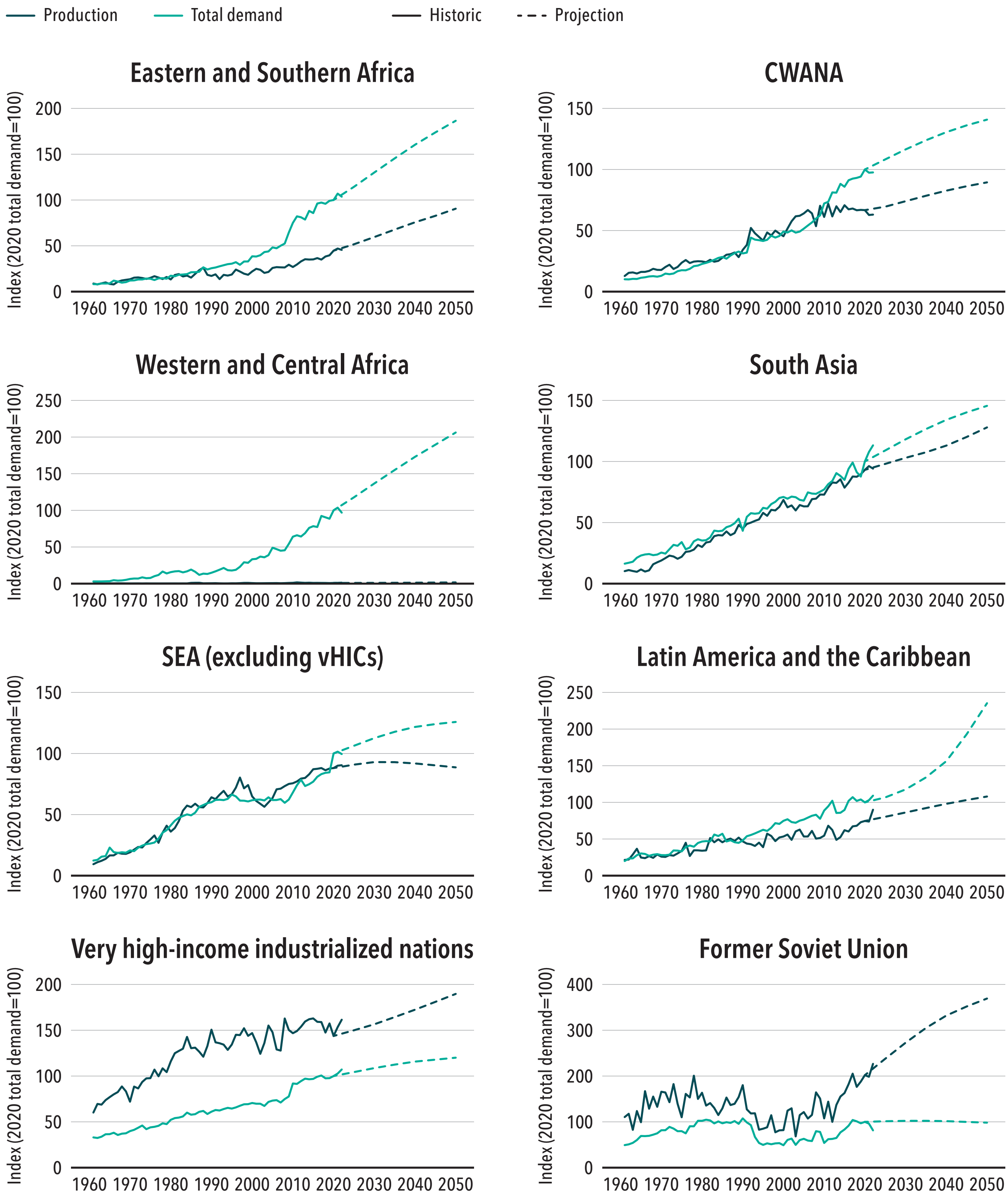
With limited progress on global greenhouse gas (GHG) emissions reductions, agriculture's role in mitigation is growing. Innovations such as biological nitrification inhibition in wheat (Subbarao et al. 2017; Leon et al. 2022) and nitrogen-efficient, stress-resilient varieties developed by CGIAR could significantly reduce GHG emissions. Additionally, wheat's comparative advantages may shift geographically. Silva et al. (2023) identify 86 million ha of potential new wheat-growing areas globally, including 25 million ha in sub-Saharan Africa suitable for rainfed cultivation without major irrigation. Yield gaps, often over 50 percent, can be addressed through improved rotations and agronomic practices like conservation agriculture. In Asia, production increases are expected to rely more on closing yield gaps than expanding cultivation areas.

These advancements underscore the need for integrated approaches combining technological innovation, CSA practices, and adaptive breeding to ensure wheat's resilience and productivity in a changing climate.

Wheat consumption is expected to grow in countries such as Bangladesh, India, Nepal, and Thailand by 2050 (Frija, Ouerghemmi, and Mottaleb 2021). Wheat is also expected to gain further importance as a major cereal in the diet of many sub-Saharan Africa countries by 2050, with increasing demand rates higher than those of other cereals (Frija, Ouerghemmi, and Mottaleb 2021). To meet the expected grain demand by mid-century, wheat production must also increase (Silva et al. 2023).

Dietary shifts from cereals toward animal proteins may reshape the global food system in the future (Kruseman et al. 2021a, 2021b). Dietary change has long been associated with changes in both the degree of urbanization and in disposable income, where the data indicate that wheat in most cases is a more desirable cereal than other coarse grains (Kruseman et al. 2021b). Although per capita consumption of global staple cereals is likely to decline in many countries, total demand will increase over the next several decades due to population growth (Rosegrant et al. 2024). Increased demand for quality and healthy food implies that the perception of wheat as a quality staple is on the rise in countries that are not traditionally wheat

FIGURE 2 Historical trends and projections in total demand for and production of wheat by region, 1961–2050



Source: Historic trends based on FAO (2024) food balance sheets. Projections based on IMPACT model results (Rosegrant et al. 2024).

Note: Index based on 2020 total demand per region = 100. An index is used to show the magnitude and direction of change rather than focusing on actual numbers. CWANA = Central and West Asia and North Africa. SEA = Southeast Asia. vHICs = very high-income countries.

consumers (Mottaleb et al. 2018a, 2018b, 2021; Frija, Ouerghemmi, and Mottaleb 2021). Higher incomes are associated with shifts from plant- to animal-based diets. In recent years in high-income countries, this trend started to reverse with the emergence of viable and more affordable plant-based alternatives. Some evidence suggests that gluten (a key protein in wheat) is likely to be an essential ingredient of affordable, high-quality, plant-based fish and meat alternatives (He et al. 2020; Zhang et al. 2021), in combination with a range of pulses. As animal-based food consumption is likely to be under pressure because of GHG emissions and other environmental concerns, wheat will continue to play a major role in the global human diet. Despite the perceived shift toward plant-based diets, considerable factors remain as barriers to a rapid dietary shift. For example, availability and accessibility as well as cultural, religious, social, economic, and legal considerations all influence consumers' food choices (Abe-Inge et al. 2023).

Figure 2 summarizes the effects of some of these issues by comparing historical trends to projections generated by the IMPACT model (Rosegrant et al. 2024). The eight panels show the production of wheat in seven main regions of the world as well as total demand, comprising food, feed, seed, and industrial uses. Some of the poorer regions of the world are historically wheat-deficit areas and will increasingly depend on imports. Projections do not take into account the effects of the Russia-Ukraine war on key supplies of food commodities (Mottaleb, Kruseman, and Snapp 2022; van Meijl et al. 2024).

KEY GAPS AND OPPORTUNITIES FOR FORESIGHT RESEARCH

Research on wheat in relation to climate change has focused on the adaptation of wheat-based systems to new situations and stressors. While work has been done on technologies that offer some level of mitigation, such as biological nitrogen inhibition (for example, Leon et al. 2022), more foresight research is needed on the potential uptake of technologies that simultaneously offer adaptation to and mitigation of climate change. The spread of new diseases is a concern that could intensify with climate change, especially in tropical and subtropical regions (Pequeno et al. 2024), requiring additional research.

With climate change, the potential production areas for different crops, including wheat, will shift. In recent years wheat production in North Africa has become increasingly difficult due to climate change-related stressors. More research is needed to identify areas with an increasing comparative advantage to grow wheat. Foresight research is also needed to guide best agronomic, varietal, and other practices for expected wheat expansion areas. Analysis needs to consider not just carbon dioxide (CO_2) and changing rainfall patterns, as was done in Jägermeyr et al. (2021), but also scenarios that take into account: the negative impact on yields of warmer night temperatures (which influence yield variance more than day temperatures do, and which are increasing faster than day temperatures); heatwaves, which are expected to be more extreme and frequent; delayed rains and less even distribution of precipitation; and floods and untimely frosts. Increased CO_2 does not mitigate any of the above and heavier rain is only useful if timely, and on soils with good infiltration rates.

Awareness is growing that animal-based diets have a strong impact on the environment. Dietary change is generally slow, but a movement toward more plant-based diets is likely. Foresight research is needed on dietary change in relation to plant-based meat products and the implications for wheat, as wheat is likely to be an important component of such a diet.

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Related chapters on the future of food system drivers and impacts, regional and national perspectives, food commodities, and foresight tools are available in our Table of Contents.

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