Matthew P. Reynolds
Hans-Joachim Braun *Editors*

Wheat Improvement

Food Security in a Changing Climate

CGIAR

CIMMYT
International Maize and Wheat Improvement Center

OPEN ACCESS

Springer

Chapter 4
Global Trends in Wheat Production, Consumption and Trade

Olaf Erenstein, Moti Jaleta, Khondoker Abdul Mottaleb, Kai Sonder, Jason Donovan, and Hans-Joachim Braun

Abstract Since its domestication around 10,000 years ago, wheat has played a crucial role in global food security. Wheat now supplies a fifth of food calories and protein to the world's population. It is the most widely cultivated crop in the world, cultivated on 217 million ha annually. This chapter assesses available data on wheat production, consumption, and international trade to examine the global supply and demand conditions for wheat over the past quarter century and future implications. There is continued urgency to enhance wheat productivity to ensure global food security given continued global population growth and growing popularity of wheat based processed foods in the Global South. To enhance productivity while staying within planetary boundaries, there is a need for substantive investments in research and development, particularly in support of wheat's role in agri-food systems in the Global South.

Keywords Wheat · Food security · Demand · Supply · Trade · Staple cereals

4.1 Learning Objectives

This chapter highlights the continued importance of wheat for global food security over the past quarter century. It aims to illustrate:

- The need to not only consider global wheat supply, but also demand and trade conditions.
- The continued need to invest in wheat productivity enhancement while staying within planetary boundaries.

O. Erenstein (✉) · K. A. Mottaleb · K. Sonder · J. Donovan · H.-J. Braun
International Maize and Wheat Improvement Center (CIMMYT), Texcoco, Mexico
e-mail: o.erenstein@gmail.com; k.mottaleb@cgiar.org; k.sonder@cgiar.org; j.donovan@cgiar.org; H.J.Braun@outlook.com

M. Jaleta
International Maize and Wheat Improvement Center (CIMMYT), Addis Ababa, Ethiopia
e-mail: m.jaleta@cgiar.org

M. P. Reynolds, H.-J. Braun (eds.), *Wheat Improvement*,
https://doi.org/10.1007/978-3-030-90673-3_4

4.2 Introduction

Wheat is one of the world's oldest and most widely used food crops, domesticated more than 10,000 years ago in the Near East's Fertile Crescent. Its domestication took place roughly around the time of rice and somewhat prior to that of maize [1]. Together, the three big global staple cereals – wheat, rice, maize – comprise a major component of the human diet, accounting for nearly half of the world's food calorie and two-fifths of protein intake. Wheat alone plays a particularly crucial role in ensuring global food/nutrition security [2, 3], supplying a fifth of global food calories and protein.

This chapter examines the global wheat supply and demand conditions over the past quarter century and explores future implications. In the subsequent sections we briefly present data and methods and then assess the state of wheat production, consumption, and international trade at the global and regional levels, before concluding.

4.3 Data and Methods

We assess available secondary data on wheat production, consumption and international trade from FAOStat [4] and complementary indicators from other sources and review associated literature.

A modified approach to calculate and map wheat calorie production and demand based on Kinnunen et al. [5] was utilized to produce Figs. 4.2 and 4.5. On the production side the SPAM 2010 [6] wheat production grid was utilized in combination with a calorie value per ton [7] to calculate wheat based energy per 10×10 km^2 pixel. Using raster calculator in ArcMap 10.8.1 this value grid was adjusted based on available data for regional production and postharvest losses [8]. Calorie allocation fractions for food use were applied on country basis, subtracting wheat used for feed and other purposes [7]. For countries without data a value of 1 was assumed for wheat utilization as food.

On the demand side population was represented by the 2017 Landscan data set [9]. This was multiplied with the country specific annual wheat calorie use by person and year [4]. For few countries without current values older FAO data and secondary sources were utilized, and for remaining gaps neighbouring countries were utilized. These values were adjusted upwards for losses related to processing, packaging, and transport as well as consumer food waste [8].

4.4 Trends in Global Wheat Production

By 2018, wheat was cultivated on an estimated 217 million (M) ha of land globally (Triennium Ending – TE2018), making it the most widely grown crop in the world. In comparison, maize has nearly 200 M ha and rice 165 M ha (Table 4.1). In terms

Table 4.1 Global cereal production indicators

		1992–1994 (TE1994)	2016–2018 (TE2018)	Relative change (%)
Wheat	Area (M ha)	220	217	−1.1%
	Production (M mt)	552	752	36.3%
	Yield (mt/ha)	2.5	3.5	37.8%
Rice (Paddy)	Area (M ha)	147	165	13%
	Production (M mt)	532	768	44%
	Yield (mt/ha)	3.6	4.6	28%
Maize	Area (M ha)	135	196	44%
	Production (M mt)	527	1146	118%
	Yield (mt/ha)	3.9	5.9	51%

With data from Ref. [4]

of production, wheat's 752 M tons globally (TE2018) is slightly less than rice (768 M tons paddy – Table 4.1), although both crops are overtaken by maize (1146 M tons, with some 57% used as feed). The divergence reflects the substantially higher maize yields, linked to widespread hybrid and input use and the higher rice yields linked to widespread irrigation. It is of interest to note that of the three main cereal staples, wheat was the only staple recording a slight area decline over the last quarter century (−1% since TE1994), whereby the substantive yield increase (+38%) was the main driver for the similarly substantive increase in production (+36%). In the case of maize, the more than doubling of production over the period was supported by both substantive yield increases and area expansion. Increases in rice production also relied on a combination of yield and area increases (Table 4.1).

Since 1961, the global area under wheat production has oscillated between 200 and 240 M ha (Fig. 4.1). Wheat area peaked around 1980 and has slowly oscillated downwards towards the current 217 M ha (TE2018). Given the relative stability of wheat area (including a modest decline over the last half century) the increase in global wheat production is explained by consistent increases in wheat yield (Fig. 4.1). Yields have steadily increased from a global average of only just over 1 ton/ha in the early 1960s to the current 3.5 tons/ha, nearly quadrupling global wheat production over the period (Fig. 4.1).

Over 120 countries distributed across Europe, Africa, the Americas, Asia and Oceania cultivate wheat [4], spanning both emerging economies and the developed world. From an agronomic perspective, wheat performs better in temperate environments. It can withstand frost and some 150 M ha of wheat is grown in areas where freezing temperatures occur during the wheat growing season. Such frost prevents many other crops from being cultivated since they are frost susceptible, except for some frost tolerant minor crops such as rye, triticale, barley, canola and some legumes. Consequently, in areas with below zero temperatures during the crop cycle

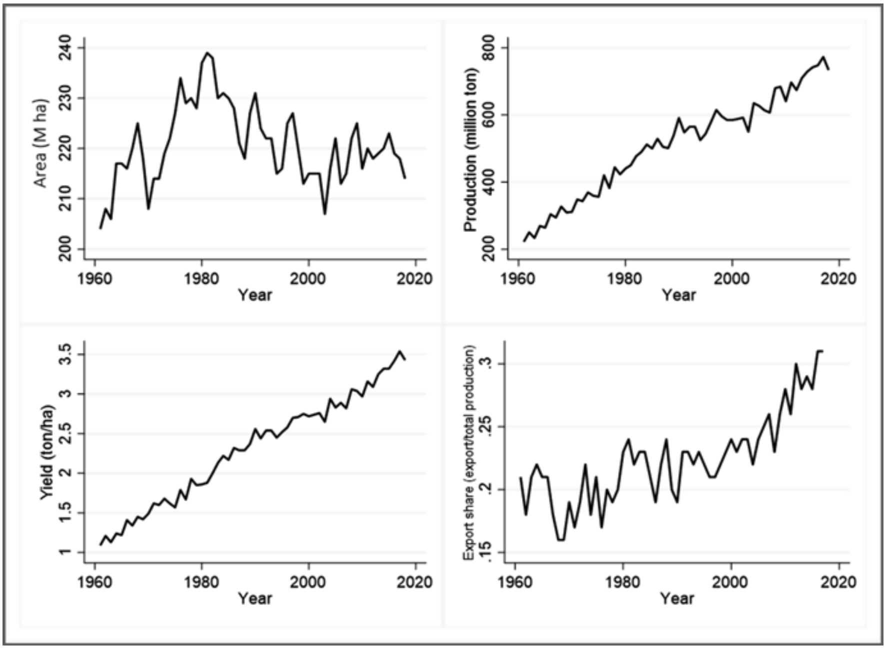

Fig. 4.1 Dynamics of key wheat indicators 1961–2018: wheat area (M ha), production (M ton), yield (ton/ha) and export share (export/total production). (Figure prepared with data from Ref. [4])

wheat thereby is the only biologically and economically feasible crop. Wheat cultivation is spread across the northern and southern latitudes, as well as in highlands and irrigated winter seasons in the lower latitudes (Fig. 4.2).

Asia contributes the most to global wheat production (44%, TE2018), followed by Europe (34%) and the Americas (15% – Fig. 4.3), with small but similar shares for Oceania and Africa (3.4–3.5%). Over the last quarter century, the relative production shares by region have remained largely similar, albeit with a 5% point decline for the Americas (down from 20% in TE1994, associated with the expansion of maize and soybean) and slight increases of 1–2% points in each of the other regions. There is a substantive heterogeneity within each of the continent's regions. For instance, about half of Asia's near 100 M ha are in South Asia, the remainder about equally split between west/central and east/south east Asia. Within South Asia wheat cultivation is concentrated in the Indo-Gangetic plains and within east/southeast Asia in north-eastern China (Fig. 4.2). There are also marked divergences in productivity (e.g., being low in west/central and high in east/southeast Asia), translating in varying regional shares in production.

Roughly 29% of the global wheat area is in low and lower-middle income countries (L/LM-ICs), contributing some 25% to the global wheat production (TE2018 – Table 4.2). This reflects somewhat lower yields (3.1 ton/ha TE2018) than the average yields of upper-middle- and high-income countries (UM/H-ICs, 3.6 ton/ha). Interestingly, the yield growth rate in the two income groups has been similar (1.4% pa – Table 4.2). A wheat area decrease (−0.3% pa) was only observed for

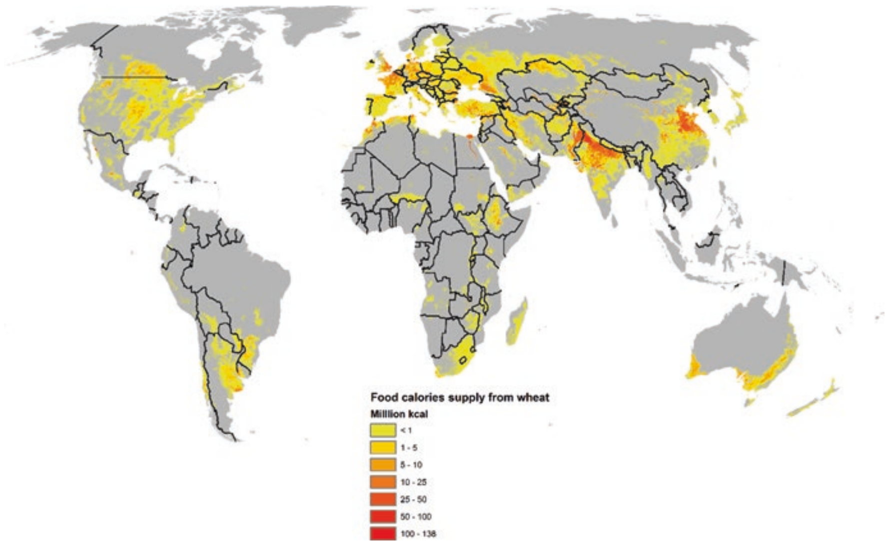

Fig. 4.2 Geography of wheat production (estimated M kcal energy produced by wheat per pixel, ca 10 × 10 km^2). Prepared using SPAM 2010 and other sources (see Sect. 4.3 for details)

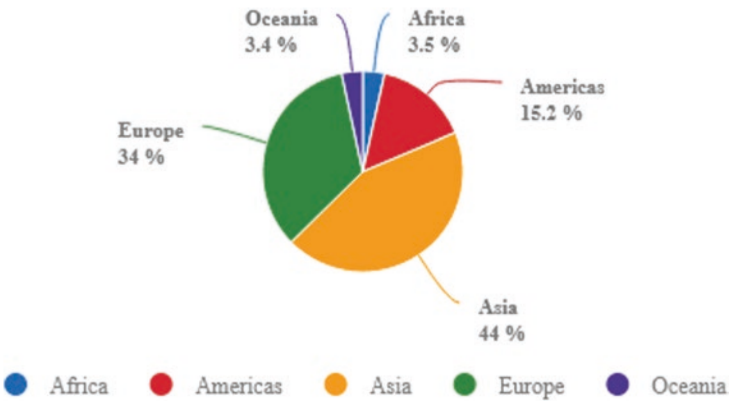

Fig. 4.3 Production shares of wheat by region, TE2018. (Figure prepared with data from Ref. [4])

UM/H-ICs, whereby production increased by only 1.1% pa. L/LM-ICs had a wheat area increase (+0.8% pa), whereby production increased by 2.2% pa (Table 4.2).

Wheat production has been dominated by a handful of countries. In TE2018, 53% of global production came from China, India, Russia, United States and France. Interestingly, these same countries have dominated wheat production since the 1960s, but their order has changed over time – with production in both China and India increasing ten-fold from some 10+ M tons each in the early 1960s to each surpassing 100 M tons currently, and becoming the top 2 global producers. India's

Table 4.2 Regional wheat production indicators

Region	Average TE2018			Average annual growth rate (TE1994–2018)		
	Area (M ha)	Production (M mt)	Yield (mt/ha)	Area (% pa)	Production (% pa)	Yield (% pa)
Asia	99.3	330.6	3.3	−0.1	1.5	1.6
South	48.9	144.3	3.0	0.6	2.2	1.5
West & central	25.3	51.9	2.2	−0.5	0.8	1.3
East & SE	25.2	134.4	5.3	−0.8	1.2	2.0
Africa	10.1	26.4	2.6	1.0	3.0	1.8
Northern	7.4	19.4	2.6	0.9	2.8	1.8
Sub-Saharan	2.7	7.1	2.6	1.7	3.5	2.0
Americas	34.7	113.9	3.3	−1.1	0.2	1.4
Northern	25.6	85.1	3.3	−1.5	−0.2	1.4
Central & South	9.1	28.8	3.2	0.6	2.0	1.5
Europe	61.7	255.6	4.1	0.4	1.6	1.1
Oceania	11.5	25.4	2.2	1.6	4.4	2.3
L/LM-IC[a]	62.0	191.4	3.1	0.8	2.2	1.4
UM/H-IC[b]	155.3	560.6	3.6	−0.3	1.1	1.4
World	217.3	752.0	3.5	0.0	1.3	1.4

With data from Ref. [4]
[a]Low & lower-middle income countries
[b]Upper-middle & High income countries

rise has been linked to the Green Revolution which combined high-yielding wheat varieties with fertilizer and irrigation and policy support. The expansion of wheat cultivation and intensification in upcoming wheat producing countries has so far not dented the dominance of the traditional top producers, albeit increased the importance of wheat production in the Global South.

The diverse environments where wheat is cultivated have led to the distinction of various wheat mega-environments (ME, see Fig. 1.3), which spread from winter production in northern latitudes to production in the warm and humid environments of Bangladesh and eastern India. The mega-environments have implications for the types of wheat grown (e.g. spring, winter; bread, durum; hardness, colour) and the relevance of associated traits (e.g. heat and drought tolerance; maturity; biotic stress tolerance – [10]; see Chap. 3). The mega-environments are associated with the prevailing wheat production systems, including intensive irrigated systems with high and stable yield potential to extensive rainfed systems with low and variable yield potential and associated input use and mechanization. The wheat production systems and productivity do not always reflect the income categorization of a particular country, with Australia's variable rainfed wheat production being a case in point.

Climate change is set to gradually shift wheat mega-environments, including increased cultivation prospects in the northern and southern latitudes, while increased stress may lead to reduced production in sub-tropical environments (including heat, drought and biotic stresses – e.g., [3, 11]). Over time new pests and diseases or new races of existing diseases, have emerged with far reaching consequences, including wheat rusts [12] and wheat blast [13]. There are also likely trade-offs between climate change adaptation and implications for wheat, with higher CO_2 levels potentially increasing yields (starch) but lowering protein content.

Wheat is far from 'a rich man's crop' for large swathes of the Global South, but pivotal to poor rural producers/consumers (and urban resource poor consumers, see Sect. 4.5). Millions of smallholders in Asia, Africa and South America are engaged in wheat cultivation for their own consumption and income generation. A range of smallholder wheat production systems exist, from rainfed with low and variable productivity in the Central-West Asia and Northern Africa region to smallholder commercial intensified areas such as the NW Indo-Gangetic plains. There is also a contrast between traditional and non-traditional wheat growing areas with implications for the role of wheat for food security and rural livelihoods and implications for innovation and system dynamics (e.g., crop-livestock interactions and use of wheat straw as animal feed). Table 4.3 summarizes the major differences for wheat between L/LM-ICs and UM/H-ICs. There is a remarkable divergence on the reliance on irrigated wheat: some three-fifths of the wheat area in L/LM-ICs being irrigated, whereas irrigated wheat accounts for only 15% in UM/H-ICs – wheat being a relatively low value crop there. The very small farm sizes in the Global South also limit options for variety choice and risk management. Such smallholders cannot grow several varieties to cover risk – they need varieties with yield stability no matter what the weather brings.

Earlier in this section we noted that since the 1960s wheat production increases have been attributed more to intensification than extensification. The challenge

Table 4.3 Global wheat dichotomy

	Low & lower-middle income countries (L/LM-IC)	Upper-middle & High income countries (UM/H-IC)
Wheat area (M ha)	62	155
Wheat production (M mt)	191	561
Wheat yield (mt/ha)	3.1	3.6
High average yields (mt/ha)[a]	6.7 (Egypt, spring wheat)	9 (Ireland, winter wheat)
Average farm size[a]	1–3 ha	Up to 5000 ha
Irrigated wheat area, %[a]	59	15
Wheat consumption (%)		
Food	79	60
Feed/seed/other	21	40

Most data from [4]
[a]Compiled by authors

remains to continue to do so in the coming decades while staying within planetary boundaries [14]. Population growth alone implies the need to produce an additional 132 M mt annually by 2050 to meet wheat food needs at current average consumption levels (see Sect. 4.5). At the same time the demands of increasing land and water scarcity with the added context of climate change are increasingly recognized.

Increasing land pressure implies the continued need to close yield gaps [15]. Wheat also adds to global water demand - with some 1000 litre per kg of grain. The unsustainable portion of the blue water footprint is particularly large in the Indus and Ganges river basins in India and Pakistan and in the north-eastern part of China [16]. Increasing water scarcity implies the continued need to improve water use and water productivity through policy, crop improvement and management (e.g., laser land leveling, drip irrigation). The intensification of wheat production also has raised concerns on environmental externalities (beyond water scarcity), including the heavy doses of chemical fertilizers used in intensive systems (particularly nitrogen). The persistently low nutrient use efficiency (stagnant at around a third over the last quarter century, particularly in China and India, [17]) has led to a quest for improvement, including sustainable intensification and climate change mitigation.

4.5 Trends in Global Wheat Consumption

Wheat has an average annual per capita food consumption of 65.6 kg globally (TE2017), which amounts to 37% of the average annual cereal consumption of 175 kg globally (TE2017, excluding beverages – [4]). Wheat is the second most consumed cereal (as food) after rice (81 kg, 46%). Wheat is consumed in 173 countries, with consumption levels exceeding 50 kg/capita/year in 102 countries [4]. In countries with strong wheat dietary traditions, to include those of in Northern Africa, West/Central Asia and Europe, per capita wheat consumption is particularly high (Table 4.4). As a group, UM/H-ICs consume 68% of global wheat, aided by above average per capita wheat consumption (Table 4.4). Asia stands out as the main aggregate consumer, with 53% of global wheat consumption followed by Europe (26%) and some 10% each in the Americas and Africa (Table 4.4).

Over the past quarter century global per capita wheat consumption has shown a slight decline in most regions and globally (Table 4.4). However, this masks a significant earlier surge in global per capita wheat consumption (55 kg – TE1963 to 70 kg – TE1993), driven by increases in Africa and Asia since the 1960s (Fig. 4.4). In Africa, per capita annual wheat consumption increased from 30 kg – TE1963 to 47 kg – TE1993 and to 49 kg – TE2017 (Fig. 4.4). In Asia, where rice is the major staple crop, corresponding figures were 29 kg – TE1963, increasing to 67 kg – TE1993 and declining slightly to 63 kg – TE2017 (Fig. 4.4), driven by changes in South and South-East Asia. In Asia, the role of China and India stands out. The two countries, which together contain more than 36% (2.8 billion) of the global population (7.7 billion – 2019, [18]), have experienced a drastic increase in wheat consumption: per capita annual wheat consumption in China and India increased from

Table 4.4 Regional wheat consumption indicators

Region	Average 2014–2017					
	Aggregate consumption[a] (M mt/year)	Per capita food consumption[b] (kg/year)	Aggregate consumption (av % pa)		Per capita food consumption (av % pa)	
			TE1994-13	2014–2017[c]	TE1994-13	2014–2017[c]
Asia	375.1	62.8	1.2	2.8	−0.5	0.5
South	146.4	67.6	1.8	2.9	0.0	0.7
West & Central	61.9	132.6	1.7	−1.3	−0.2	−0.5
East & SE	166.8	49.6	0.7	11.8	−0.6	0.3
Africa	70.7	49.5	3.3	1.0	0.1	−0.7
Northern	45.2	143.8	2.6	−0.1	−0.1	−0.2
SSA	25.5	25.2	5.1	1.0	1.9	−0.7
Americas	78.7	61.4	0.7	2.3	−0.1	−0.2
Northern	41.4	80.4	0.05	4.4	−0.2	0.4
Central & South	37.2	50.5	1.5	−0.1	0.1	−0.6
Europe	186.8	110.5	0.2	2.5	0.1	0.2
Oceania	8.4	75.4	3.5	3.0	0.1	0.4
L/LM-IC[d]	225.5	56.4	2.0	1.9	−0.1	−0.2
UM/H-IC[e]	486.0	72.7	0.6	2.7	−0.4	−0.1
World	711.5	65.5	1.0	2.4	−0.4	−0.1

With data from Ref. [4]
[a]Domestic supply quantities in Food Balance Sheet (FBS), across uses
[b]Food supply quantity (kg/capita/year) in FBS (i.e. net of non-food uses)
[c]New FBS method since 2014 [4]
[d]Low and Lower-Middle income countries
[e]Upper-Middle and High income countries

23/29 kg – TE1963 to 78/60 kg – TE1993 and now averaging 63/61 kg – TE2017. Still, given the sheer size of China and India there is a marked within country heterogeneity of wheat consumption. In NW India per capita wheat consumption surpasses 100 kg pa; whereas in SE India rice consumption prevails. Similarly, wheat consumption is more pronounced in NE China and E Pakistan. Figure 4.5 visualizes the heterogeneity in wheat consumption globally and highlights some of the within country variations.

The role of wheat in diets around the globe has been particularly dynamic up to the 1990s affected by income growth, urbanization, and associated life-style changes. Globally GDP per capita has increased by 3.5% per annum (1961–2019, from US$3.9k pc TE1963, to US$11.1k pc in 2019 at 2010 constant prices – [19]). Urbanization has increased from a little more than 34% of global population in 1961 to nearly 56% off late [19]. On the one hand, the nutrition transition posits non-cereal food consumption to increase with increasing GDP per capita and

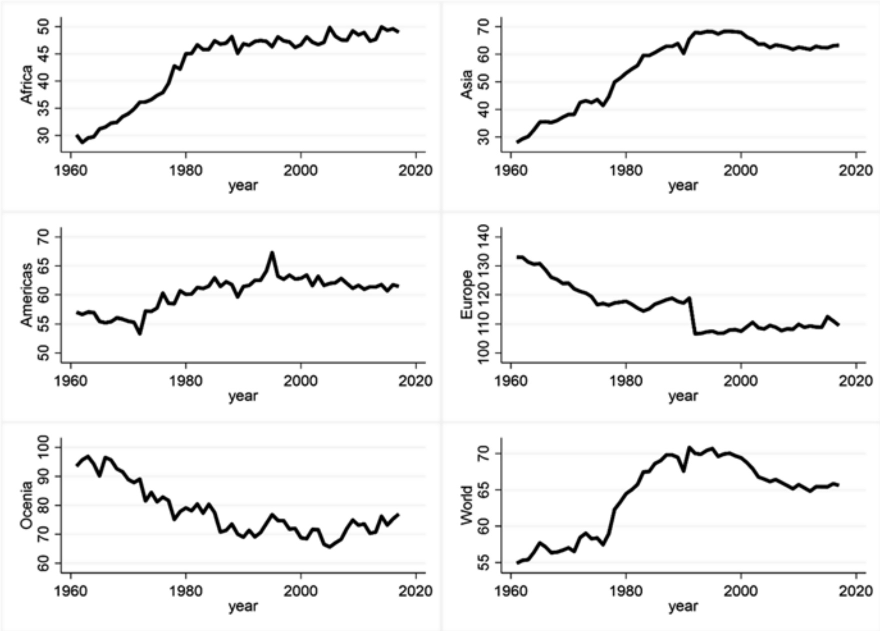

Fig. 4.4 Per capita wheat consumption trends by major regions, 1961–2017. (Figured prepared with data from Ref. [4])

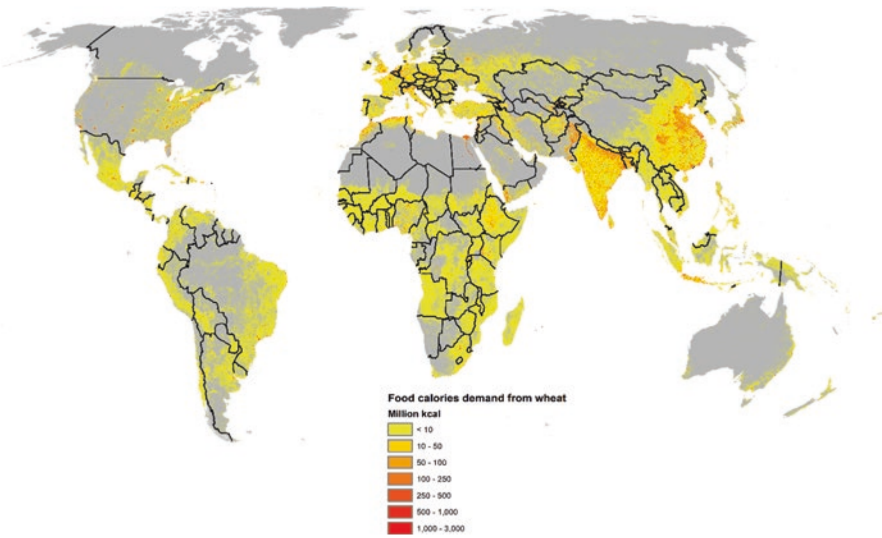

Fig. 4.5 Geography of wheat consumption (estimated M kcal food energy consumed from wheat per pixel, ca 10 × 10 km^2). Prepared using data from various sources (see Sect. 4.3 for details)

urbanization. On the other hand, wheat is a special case, with its numerous derived processed food products. Diversification of traditional diets as a result of growing economies, increased global trade, 'modernization' of tastes and consumer fads has boosted per capita consumption of wheat flour in several Asian and SSA countries [1]. An increasing number of empirical studies have highlighted wheat consumption to be increasing particularly in the global South associated inter alia with increasing incomes, rapid urbanization and the allied changes in the lifestyle including India [20], Bangladesh [21] and SSA [22]. This is further aided by changes in the food processing sector and the ability to generate cheap processed wheat-based foods and making them available across the globe.

In addition to dietary change, population growth will continue to add to wheat demand. The global population is set to increase by 2 billion from 7.7 billion currently to a projected 9.7 billion by 2050 (8.9–10.7 billion depending on low and high-fertility assumption rates – [18]). Assuming a constant annual per capita consumption, this implies a potential annual increase of 132 M mt of wheat as food by 2050 (106–224 M mt depending on fertility assumption).

Wheat is primarily produced for food (66% of global production) but a fifth of the grain is used as feed. Over time the feed use share has been steadily increasing globally, from 9% in TE1963 to 18% in TE1993 and the latest 21% (TE2017). Conversely, the food use share declined from 74% in TE1963 to 69% in TE1993 and the latest 66% (TE2017). High seed rates imply 5% of production is used as seed, with remainder divided between losses, processing and non-food uses (Table 4.5). Wheat use presents a marked divergence between country income status. In L/LM-ICs food use predominates (79%), with feed use only 10%; and relatively lower seed and processing use, and higher losses (5%). In contrast, in UM/H-ICs food use drops to 60%, with feed use increasing to 26%; and relatively higher seed, processing and non-food uses, and lower losses (Table 4.5). Furthermore, feed use is concentrated in selected geographies, being particularly high in Australia, followed by Europe and Eastern Asia. Food use is particularly high in South Asia, SSA and Latin America (Table 4.5). In SSA much of the wheat consumption is concentrated among urban populations with supplies derived largely from imports [22].

Various classes of wheat exist with varying use, including various bread wheats (such as Hard Red Winter (HRW), Hard Red Spring, Soft Red Winter (SRW), Hard White and Soft White) and Durum wheat (for pasta and couscous). These bread wheat classes vary in their milling characteristics for bread flour; baking characteristics for pan breads; and processing characteristics for Asian noodles, hard rolls, flat breads, cakes, cookies, snack foods, crackers and pastries; and improving blending (also see Chap. 11). There is often a preference for white wheat in relation to flour extraction and the colour for whole grain products like chapati. Other uses include industrial production of starch, malt, dextrose, gluten, and alcohol.

Wheat alone contributes 18% of the total dietary calories and 19% of proteins globally (Table 4.6). On average, the daily dietary energy intake per capita was 530 kcal from wheat, similar to rice (550 kcal, 19%) compared to a total intake of 2907 kcal (of which 1216 kcal from cereals). The average energy from wheat was

Table 4.5 Wheat utilization, by region, average 2014–2017

Region	Average use (% of domestic supply)					
	Food	Feed	Seed	Losses	Processing	Other uses (non-food)
Asia	73.5	16.1	4.1	3.6	0.4	2.2
South	84.7	4.3	4.1	5.3	0.0	1.7
West & Central	64.9	17.4	7.2	4.5	1.7	3.5
East & SE	67.0	25.9	3.0	1.9	0.3	2.1
Africa	74.9	12.2	1.6	5.6	0.2	4.8
Northern	69.8	17.1	2.0	7.8	0.0	3.3
SSA	83.9	3.7	0.8	1.9	0.6	7.4
Americas	75.6	12.3	4.5	5.4	0.2	4.1
Northern	67.7	19.1	6.3	7.3	0.4	2.4
Central & South	84.7	4.6	2.5	3.3	0.0	6.1
Europe	43.8	36.0	9.4	2.1	4.3	4.7
Oceania	28.3	48.6	7.8	3.4	2.2	11.2
L/LM-IC[a]	79.0	9.5	3.4	5.1	0.2	2.7
UM/H-IC[b]	59.5	26.1	6.3	2.9	1.9	3.7
World	65.7	20.9	5.3	3.6	1.4	3.4

With data from Ref. [4]
[a]Low and Lower-Middle income countries
[b]Upper-Middle and High income countries

however more than double its global average in West/Central Asia and Northern Africa (>1000 kcal), representing over a third of their total energy intake. As a group, the wheat calorie share is similar for UM/H-ICs and L/LM-IC's (Table 4.6).

On average, globally the daily protein intake per capita from wheat was 16 g or 19% of the daily protein intake (82 g, and half the proteins provided by cereals, 32 g). The average protein intake from wheat was somewhat higher in UM/H-ICs (18 g). However, wheat intake represented 20% of protein intake in L/LM-IC's, reflecting more intensive use of wheat as food and lower food intakes in L/LM-IC's. The contribution of wheat as a source of daily protein intake is again substantively higher for regions like Northern Africa and West/Central Asia (38%). Wheat also provides a modest source of daily fat (2.5 g representing 3% of daily intake – Table 4.6).

Wheat's nutritional contribution plays of an important role in addressing the triple burden of undernutrition (hunger), micronutrient malnutrition and overnutrition (overweight, obesity). Indeed, in addition to being a major source of dietary energy and proteins, wheat also provides essential micronutrients and diverse non-nutrient bioactive food components (24). Still, various avenues remain to strengthen wheat's nutritional contribution, including active work on bio- and industrial fortification (e.g. see Chap. 12). There is also considerable potential in improving processing and intake forms (also see Chap. 11). For instance, current intakes of whole grain foods should at least double compared with national dietary guidelines (except in N America, [23]). Whole grain wheat is an important source of dietary fibre with associated health benefits for controlling non-communicable diseases [24].

Table 4.6 Regional wheat food supply indicators

Region	Wheat and products in food supply (TE2017)			Wheat share in total food supply (%/capita/day, TE2017)		
	Food supply (kcal/capita/day)	Protein supply quantity (g/capita/day)	Fat supply quantity (g/capita/day)	Kcal share (%)	Protein supply share (%)	Fat supply share (%)
Asia	527	15.8	2.6	18.7	19.8	3.5
South	567	16.3	2.7	22.6	25.3	4.9
West & Central	1084	32.7	5.2	36.3	37.7	5.6
East & SE	342	10.4	1.6	11.5	12.3	2.1
Africa	392	11.7	1.7	15.0	17.2	3.2
Northern	1136	34.4	5.0	35.5	37.6	7.5
SSA	248	7.4	1.1	9.8	11.2	1.9
Americas	464	13.7	2.1	14.1	14.6	1.7
Northern	608	19.5	3.3	16.4	17.4	2.0
Central & South	343	9.5	1.3	11.2	11.1	1.4
Europe	846	26.3	3.5	25.1	25.7	2.7
Oceania	602	19.1	2.6	18.6	18.6	1.8
L/LM-IC[a]	464	13.4	2.1	18.3	20.2	3.8
UM/H-IC[b]	583	18.0	2.8	18.2	18.9	2.6
World	530	16.0	2.5	18.2	19.4	3.0

With data from Ref. [4]
[a]Low and Lower-Middle income countries
[b]Upper-Middle and High income countries

4.6 Wheat Prices and Trade

Some of the world's biggest wheat producers – China, India – are largely self-sufficient. Nonetheless, wheat is the most widely globally traded cereal, with 25% of global wheat production being exported (TE2018),[1] up from 19% a decade earlier [1]. The global trade reflects a marked spatial disparity between where wheat is produced and where it is consumed (Figs 4.2 and 4.5; [5]). This underpins an active global wheat trade linking surplus production areas in the northern and southern latitudes (net exporters in Europe, Northern America and Australia) to the deficit areas in the lower latitudes (net importers in Africa, Asia and Latin America – Table 4.7). This leads to a marked disparity between countries by income groups: L/LM-ICs being net importers and UM/H-ICs net exporters (Table 4.7). Top exporting

[1] 190 M mt of wheat being traded internationally against a global production of 768 M mt in the TE2018 (average import-export). This compares to 161 M mt traded for maize the 2nd most widely traded – but representing 14% given larger production of 1146 M mt (also see Table 4.1; [4]) and primarily exported for feed).

Table 4.7 Regional wheat import/export indicators

Region	Wheat net imports: Annual average (M mt/year, TE2018)	Wheat net imports: Annual growth rate (av % pa, TE1994-18)	Top net importing countries (net import M mt/year, TE2018)
Asia	68.0	2.7	
South	9.8	6.9	Pakistan (−0.6); Sri Lanka (+1.1); India (+2.2); Bangladesh (+5.7);
West & Central	17.3	5.3	Kazakhstan (−4.9); Uzbekistan (+1.6); Saudi Arabia (+2.1); Yemen(+3.0); Turkey (+5.0);
East & SE	41.0	2.6	Rep Korea (+4.3); Vietnam (+4.7); Japan (+5.7); Philippines (+5.7); ***Indonesia (+10.3)***
Africa	46.4	4.8	
Northern	28.4	4.0	Tunisia (+2); Sudan (+2.1); Morocco (+4.7); ***Algeria (+8.3); Egypt (+10.3)***
SSA	17.9	6.9	Cameroon (+0.7); Ethiopia (+1.5); South Africa (+1.7); Nigeria (+5.0)
Americas	−34.9	−0.7	
Northern	−43.3	−0.7	**Canada (−21.6); US (−21.9)**
Central & South	8.4	3.3	Argentina (−11.7); Colombia (+1.9); Peru (+2.0); Mexico (+4.1); ***Brazil (+6.1)***
Europe	−69.0	−25.3	**Russia (−32.9); Ukraine (−17.3); France (−17.0);** ***Spain (+6.0)***; ***Italy (+7.3)***
Oceania	−15.9	−4.2	**Australia (−16.7)**; Papua New Guinea (+0.2); New Zealand (+0.5)
L/LM-IC[a]	52.7	3.0	
UM/H-IC[b]	−58.1	−3.5	

With data from Ref. [4]
[a]Low and Lower-Middle income countries
[b]Upper-Middle and High income countries

countries include Russia, United States, Canada, Ukraine, France and Australia, each exporting 16–33 M mt/year (TE2018, Table 4.7). Off late (TE2018), top importers include Indonesia, Egypt, Algeria, Italy, Brazil and Spain; each importing 6–10 M mt/year; with a number of other countries also importing substantive amounts (e.g., Bangladesh, Japan, Philippines, Turkey, Nigeria 5–6 M mt – Table 4.7). Imports thereby are spread far and wide across a range of countries, but still creating substantive foreign exchange outlays for annual imports and import dependence for food security, particularly given its prevalence across L/LM-ICs.

There is still substantial heterogeneity in each region. For instance, the Mediterranean region includes major wheat deficit areas, both for Europe (Italy, Spain) and northern Africa; Latin America includes major import reliance with exports from the southern cone; and Oceania's net exports hinges on Australia's harvests. More worrying is that import dependence continues to increase for the L/LM-ICs, whereas exports increase for the UM/H-ICs, particularly Europe and Australia (Table 4.7). The highest growth in wheat imports were observed for sub-Saharan Africa and South Asia (Bangladesh), followed by West and Central Asia (Table 4.7). The increased burden of wheat imports has reignited interests in self-sufficiency, from traditional wheat producers like Ethiopia to across Africa. Indeed, the current high levels of spatial decoupling between production and consumption are set to increase further over the coming decades [25].

Underlying the global wheat trade are also some wheat processing and consumption considerations. Turkey is a case in point, being notionally self-sufficient in terms of domestic wheat production and consumption. Still, Turkey is a major importer of wheat grain and the leading exporter of wheat flour, with imports not being taxed if equivalent of flour exported. Australia is a main wheat provider for Asian noodles, with e.g., a preference for Australian Standard white being relatively low in protein. Adding to global trade is a decoupling between the production of red wheat in the Americas and Europe and a preference to consume white wheat products, with much of red wheat being exported, including for industrial uses.

Over the last decades wheat prices nominally increased by 37%, from US$143/ton (average US HRW/SRW) in TE1994 to US$197/ton in TE2019. HRW tended to have a somewhat higher price compared to SRW, but the prices have converged in recent years (Fig. 4.6). The highest prices over the period were observed in 2008–2009 (US$240–250/ton) linked to the global food crisis and in 2012–2014 with even higher nominal prices of up to USD 300/ton (2013). The price oscillations over the last 10+ years largely track the pattern of urea fertilizer (Fig. 4.6), albeit that urea prices increased by 139% over the quarter century (from US$99/ton in TE1994 to US$236 in TE2019). The ratio of wheat-to-urea prices thereby decreased from 1.45 to only 0.84 over the quarter century. Other staple cereals saw somewhat

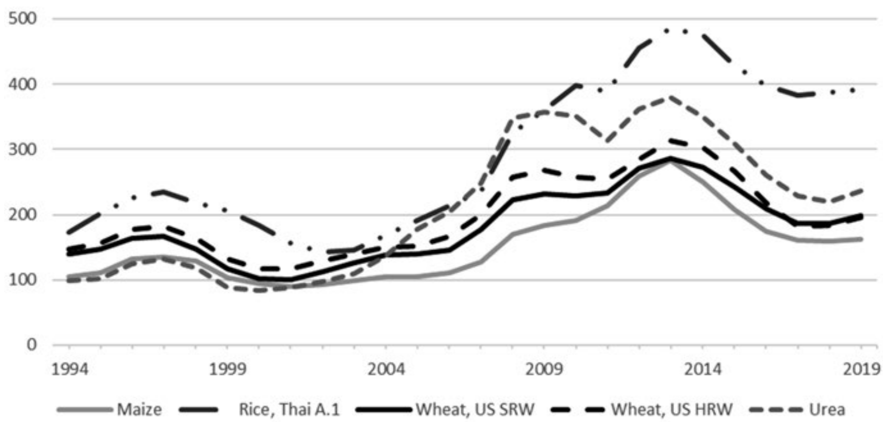

Fig. 4.6 Selected cereal and urea prices (nominal US$/ton, TE1994-2019). (Figure prepared with data from Ref. [26])

similar price trends over the period, albeit that the increases in nominal prices were somewhat more pronounced for maize (+56%) and particularly for rice (+127%).

The global food crisis and subsequent Arab Spring made their mark on the supply and demand dynamics. Prior to these there were concerns of a longer term decline of wheat prices due to continued wheat productivity growth [2]. The surge in global prices and import dependence sparked social unrest and the Arab Spring when these were passed on to domestic price increases and increased scarcity of wheat and food supply instability (e.g. [27]). The Arab Spring has been associated with the failure of the wheat crop in China [28], illustrating how production shocks can contribute to wheat price spikes. Such concerns have been growing in the context of climate change with increased weather shocks (e.g., heat, droughts, excessive water) and biotic shocks (diseases and pests). Such concerns are also not limited to wheat, as extreme weather conditions can affect global agricultural production across 'breadbaskets' and crops at the same time, leading to synchronized global breadbasket failures and fallout thereof [29]. Global wheat stocks could help buffer shocks, but outside China, global wheat stocks have been oscillating around the current 150 M tons. China has however progressively grown its wheat stock since 2006 after setting a guaranteed floor price to ensure food security and stability [30]. China now has more than half (52%) of global stocks [31]. China thereby is well placed to buffer domestic shocks, albeit less likely to release any onto the global market, also as Chinese domestic prices are relatively high and not internationally competitive [30].

International trade brings into play potential distortions and (dis-)incentives. Domestic (grain) price support (e.g., floor prices, taxes/subsidies, import barriers) can increase domestic relative to world market prices and can boost domestic production as observed in China and India [32, 33]. China's grain subsidy program has been labelled as the largest food self-sufficiency project in the Global South [34]. Agricultural input subsidies provide additional distortions – typically incentivizing intensification but also creating environmental externalities with their excessive use (e.g., nitrogen; irrigation – [32]). Export support (e.g., subsidies) aids domestic surplus producers but undermines producers in importing countries. Removal of agricultural supports globally would raise international wheat prices and potentially increase the cost for many net-importing countries, although also increase incentives for domestic production and import substitution. In addition to the competitive distortions induced by agricultural supports, concerns have also been raised by the underlying resource demands, e.g., the virtual water implicit in the global wheat trade and environmental externalities.

4.7 Key Concepts

This chapter highlighted the continued importance of wheat for global food security over the past quarter century and future implications. It thereby highlighted the need to not only consider global wheat supply, but also demand and trade conditions.

Finally, it highlighted the continued need to invest in wheat productivity enhancement while staying within planetary boundaries.

4.8 Conclusion

Wheat plays a crucial role for global food security and is a critical component in agri-food systems across the globe. It is the most widely grown crop in the world in terms of area. It provides a fifth of food calories and protein to the world's population. It is the most widely internationally traded cereal reflecting the marked spatial disparity between supply and demand. Global wheat production has shown steady growth, mainly propelled by wheat yield increases and wheat cultivation intensification rather than extensification in the form of land expansion.

The paper summarized the state of wheat production, consumption, and international trade at the global and regional levels. It provides a broad-brush appraisal, focusing on the last quarter century. Still, the analysis could be strengthened by improved data to allow for more detailed spatial, dynamic, and political analysis. The sheer size, heterogeneity and evolution of the global wheat economy calls for more detailed analysis about wheat and its role in food systems, including enhanced insights into the associated drivers and modifiers. The political economy of wheat also merits more attention, given the vested interests of subsidized production and the export and processing industries and increasing wheat consumption/production by poor consumers/farmers in the Global South.

With continued global population growth and growing popularity of wheat based processed foods in the Global South there is continued urgency to ensure further transformation of wheat agri-food systems, including sustainable intensification of wheat production to stay within planetary boundaries. The further transformation of wheat production calls for a tripartite contribution of improved germplasm, improved crop management and improved policy. Improved germplasm is particularly needed to continue to raise the wheat yield frontier (yield potential), make it more resilient and address emerging challenges and opportunities (also see Chaps. 7 and 21). This clearly includes climate change which is set to influence wheat production systems and aggravate biotic and abiotic stresses. But it also includes increased attention to quality and demands from consumers and the processing industry (also see Chap. 11). Improved crop management is particularly needed to close yield gaps and stay within planetary boundaries, including reduced environmental externalities linked to water, land and nutrients (also see Chap. 31). Improved policy is particularly needed to create the enabling environment, including value chains, markets and prices and support services and should be dynamic considering the general economic transformation context.

These improvements call for substantive investments in public research and development, particularly in support of wheat agri-food systems in the Global South. There is a general misalignment between private and public interests in wheat germplasm improvement and therefore a need to strengthen the enabling environment and to maintain public support. In the context of the Global South, there is no royalty collection system linked to varietal use (like e.g., Australia's) nor immediate prospects for proprietary varieties like hybrid wheat. Wheat germplasm improvement and research in the Global South will remain in the public domain for the coming decades, including the need for continued funder and CGIAR support; with the role of the private sector mainly limited to contracted seed multiplication (also see Chap. 2). Less obvious too is that much of the needed investments imply maintenance research: the need to keep running as standing still is not an option. Much of crop improvement indeed relies on maintenance breeding – maintaining the yield potential against the evolving biotic and abiotic stresses (also see Chaps. 8, 9, 10, 19, 20, 22 and 23). In much the same way crop management includes doing more with less and reducing environmental externalities. And much of improved policy should ensure the incentives and societal needs are aligned. Much of this may thus not result in visible productivity increases – but should reduce productivity erosion and externalities over time. But taken together the tripartite approach should go a long way to raise global wheat security and stay within planetary boundaries over the coming decades.

References

1. Awika J (2011) Major cereal grains production and use around the world. In: Awika J, Piironen V, Bean S (eds) Advances in cereal science: implications to food processing and health promotion. American Chemical Society, Atlantic City, pp 1–13
2. Dixon J (2007) The economics of wheat: research challenges from field to fork. In: Buck H, Nisi J, Salomon N (eds) Wheat production in stressed environments. Springer, Dordrecht, pp 9–22
3. Shiferaw B, Smale M, Braun H, Duveiller E, Reynolds MP, Muricho G (2013) Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. Food Sci 5:291–317. https://doi.org/10.1007/s12571-013-0263-y
4. FAOStat (2020) FAO Stat. http://www.fao.org/faostat
5. Kinnunen P, Guillaume JHA, Taka M, D'Odorico P, Siebert S, Puma MJ, Jalava M, Kummu M (2020) Local food crop production can fulfil demand for less than one-third of the population. Nat Food 1:229–237. https://doi.org/10.1038/s43016-020-0060-7
6. International Food Policy Research Institute (2019) Global spatially-disaggregated crop production statistics data for 2010 version 2.0. In: International food policy research I. Harvard Dataverse
7. Cassidy ES, West PC, Gerber JS, Foley JA (2013) Redefining agricultural yields: from tonnes to people nourished per hectare. Environ Res Lett 8:34015. http://doi.org/10.1088/1748-9326/8/3/034015
8. FAO (2011) Global food losses and food waste: extent, causes and prevention. FAO, Rome
9. Bright EA, Rose AN, Urban ML, McKee J (2018) LandScan 2017 high-resolution global population data set. Computer software. Version 00. https://www.osti.gov/biblio/1524426
10. Braun HJ, Atlin G, Payne T (2010) Multi-location testing as a tool to identify plant response to global climate change. In: Reynolds M (ed) Climate change and crop production, CABI climate change series. CABI Publishing, Wallingford, pp 115–138
11. Xiong W, Asseng S, Hoogenboom G, Hernandez-Ochoa I, Robertson R, Sonder K, Pequeno D, Reynolds M, Gerard B (2020) Different uncertainty distribution between high and low

latitudes in modelling warming impacts on wheat. Nat Food 1:63–69. https://doi.org/10.1038/s43016-019-0004-2

12. Singh RP, Hodson DP, Huerta-Espino J, Jin Y, Njau P, Wanyera R, Herrera-Foessel SA, Ward RW (2008) Will stem rust destroy the world's wheat crop? Adv Agron 98:271–309. https://doi.org/10.1016/S0065-2113(08)00205-8
13. Mottaleb KA, Singh PK, Sonder K, Gruseman G, Tiwari TP, Barma NCD, Malaker PK, Braun HJ, Erenstein O (2018) Threat of wheat blast to South Asia's food security: an ex-ante analysis. PLoS One 13. https://doi.org/10.1371/journal.pone.0197555
14. Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, Garnett T, Tilman D, DeClerck F, Wood A, Jonell M, Clark M, Gordon LJ, Fanzo J, Hawkes C, Zurayk R, Rivera JA, De Vries W, Majele Sibanda L, Afshin A, Chaudhary A, Herrero M, Agustina R, Branca F, Lartey A, Fan S, Crona B, Fox E, Bignet V, Troell M, Lindahl T, Singh S, Cornell SE, Srinath Reddy K, Narain S, Nishtar S, Murray CJL (2019) Food in the Anthropocene: the EAT Lancet Commission on healthy diets from sustainable food systems. Lancet 393:447–492. https://doi.org/10.1016/S0140-6736(18)31788-4
15. Fader M, Rulli MC, Carr J, Dell'Angelo J, D'Odorico P, Gephart JA, Kummu M, Magliocca N, Porkka M, Prell C, Puma MJ, Ratajczak Z, Seekell DA, Suweis S, Tavoni A (2016) Past and present biophysical redundancy of countries as a buffer to changes in food supply. Environ Res Lett 11:55008. https://doi.org/10.1088/1748-9326/11/5/055008
16. Mekonnen MM, Gerbens-Leenes W (2020) The water footprint of global food production. Water 12:2696. https://doi.org/10.3390/w12102696
17. Omara P, Aula L, Oyebiyi F, Raun WR (2019) World cereal nitrogen use efficiency trends: review and current knowledge. Agrosyst Geosci Environ 2:5. https://doi.org/10.2134/age2018.10.0045
18. UN-DESA World population prospects (2019). https://population.un.org/wpp/
19. WorldBank (2020) Data Bank. https://databank.worldbank.org
20. Mittal S (2007) What affects changes in cereal consumption? Econ Polit Wkly 42:444–447. http://www.jstor.org/stable/4419216
21. Mottaleb KA, Rahut DB, Kruseman G, Erenstein O (2018) Changing food consumption of households in developing countries: a bangladesh case. J Int Food Agribus Mark 30:156–174. https://doi.org/10.1080/08974438.2017.1402727
22. Mason NM, Jayne TS, Shiferaw B (2015) Africa's rising demand for wheat: trends, drivers, and policy implications. Dev Policy Rev 33:581–613. https://doi.org/10.1111/dpr.12129
23. Springmann M, Spajic L, Clark MA, Poore J, Herforth A, Webb P, Rayner M, Scarborough P (2020) The healthiness and sustainability of national and global food based dietary guidelines: modelling study. BMJ 370:m2322. https://doi.org/10.1136/bmj.m2322
24. Poole N, Donovan J, Erenstein O (2021) Agri-nutrition research: revisiting the contribution of maize and wheat to human nutrition and health. Food Policy 100:101976. https://doi.org/10.1016/j.foodpol.2020.101976
25. Fader M, Gerten D, Krause M, Lucht W, Cramer W (2013) Spatial decoupling of agricultural production and consumption: quantifying dependences of countries on food imports due to domestic land and water constraints. Environ Res Lett 8:14046. https://doi.org/10.1088/1748-9326/8/1/014046
26. WorldBank (2020) World Bank commodities price data (The pink sheet). http://www.worldbank.org/commodities
27. D'Amour C, Anderson W (2020) International trade and the stability of food supplies in the Global South. Environ Res Lett 15:074005. https://doi.org/10.1088/1748-9326/ab832f
28. Sternberg T (2012) Chinese drought, bread and the Arab Spring. Appl Geogr 34:519–524. https://doi.org/10.1016/j.apgeog.2012.02.004
29. Gaupp F, Hall J, Hochrainer-Stigler S, Dadson S (2020) Changing risks of simultaneous global breadbasket failure. Nat Clim Chang 10:54–57. https://doi.org/10.1038/s41558-019-0600-z
30. Hunt N (2018) Global wheat supply to crisis levels; big China stocks won't provide relief. Reuters

31. Jamieson C (2020) Canada markets: a look at USDA's growing global wheat stocks estimates. https://www.dtnpf.com/agriculture/web/ag/blogs/canada-markets/blog-post/2020/05/13/look-usdas-growing-global-wheat
32. Gulati A, Narayanan S (2003) The subsidy syndrome in Indian agriculture. Oxford University Press, New Delhi
33. Qian J, Ito S, Zhao Z, Mu Y, Hou L (2015) Impact of agricultural subsidy policies on grain prices in China. J Fac Agric Kyushu Univ 60:273–279
34. Yi F, Sun D, Zhou Y (2015) Grain subsidy, liquidity constraints and food security – impact of the grain subsidy program on the grain-sown areas in China. Food Policy 50:114–124. https://doi.org/10.1016/j.foodpol.2014.10.009