Chapter

Wheat as a Nutritional Powerhouse: Shaping Global Food Security

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Abstract

Wheat (*Triticum* spp.), known as the "golden grain," plays an indispensable role in global food security, providing approximately 20% of the world's protein and caloric intake. As a dietary staple for over 35% of the global population, wheat's high-yielding and disease-resistant varieties introduced during the Asian Green Revolution significantly transformed agricultural productivity. The major producers of wheat in 2022 were China, India, Russia, and the European Union, with a total production of about 778 million metric tons. Over 35% of the world's population depends on wheat as a staple meal. It serves as the leading source of plant-based protein, with a protein content of about 13%, higher than most major cereals. Additionally, biofortification programs have enhanced wheat's nutrient profile to combat malnutrition and hidden hunger, especially in impoverished regions. Wheat has an equally significant socio-economic impact because of its capacity to sustain millions of farmers and strengthen national economies through trade and employment. With an estimated $50 billion in worldwide trade, wheat is a crucial commodity for food security and international markets. The importance of whole wheat in sustainable agriculture is highlighted by initiatives to increase its consumption, enhance storage facilities, and lower post-harvest losses. There will be 10 billion people on the earth by 2050, so ensuring sustainable wheat production and equitable distribution is still crucial. Furthermore, despite climatic change and declining soil fertility, the study highlights wheat's economic importance, agronomic advantages, and nutritional worth.

Keywords: wheat, global food, food security, sustainable, hidden hunger, biofortification

1. Introduction

Wheat (*Triticum* spp.), belonging to the Poaceae (Gramineae) family, has been a cornerstone of human civilization for over 10,000 years [1]. Its versatility, adaptability to diverse climates, ease of storage, and high caloric and nutritional value make it a key player in addressing global food demands. Accounting for 20% of daily caloric and protein intake, wheat is a vital component of the human diet and ranks as the second-most significant food crop in developing nations after rice [2]. It supports food security for an estimated 80 million people worldwide. Traditionally, food insecurity

has been addressed by increasing the production of cheap, high-calorie staple crops. However, the growing prevalence of micronutrient malnutrition necessitates a balanced focus on both staple crops like wheat and nutrient-rich foods. As a dietary staple for over 35% of the global population, wheat transcends cultural and geographical boundaries [3]. Rich in carbohydrates, dietary fiber, and essential nutrients, it contributes to human health and serves as a versatile ingredient in various food products.

Wheat cultivation also underpins the livelihoods of millions of farmers and supports agricultural economies globally. Bread wheat (hexaploid) accounts for 95% of global production while durum wheat (tetraploid), commonly known as pasta wheat, constitutes the remaining 5% [4]. Durum wheat thrives in dry Mediterranean climates and is used in bread, pasta, and regional cuisines like couscous and bulgar. Additionally, ancient wheat varieties such as einkorn, emmer, and spelt (collectively known as farro in Italy) continue to be cultivated in regions like Spain, Turkey, the Balkans, and the Indian subcontinent [5]. Modern wheat varieties are typically amber-colored, but colored wheat varieties rich in anthocyanins and other phytochemicals are gaining popularity for their health benefits [6, 7]. Purple wheat was developed in the nineteenth century, and blue wheat emerged in the twentieth century through interspecific crossbreeding of *Triticum aestivum* with wild wheat species like *Thinopyrum ponticum*, *Triticum monococcum*, and *Th. Bessarabicum* [8]. These advancements reflect the crop's genetic diversity, with approximately 25,000 varieties adapted to temperate climates [9]. Under optimal conditions, including adequate water, mineral fertilizers, and effective pest and disease control, wheat yields can surpass 10 tonnes per hectare, making it a preferred crop in temperate regions [10]. Harvesting methods include conventional practices and mechanical combine harvesters. Proper storage requires moisture content below 15% to prevent spoilage and pest infestation. Wheat's significance extends beyond nourishment, encompassing its critical role in global food security, agricultural economies, and human health [11]. Ongoing research and innovation in wheat breeding and cultivation will ensure its continued contribution to sustainable food systems.

Wheat occupies a central position in the history of the Asian Green Revolution, serving as a cornerstone of the agricultural transformations that reshaped the region's food systems [12]. During the mid-twentieth century, Asia grappled with recurring food shortages, malnutrition, and widespread hunger exacerbated by rapid population growth and limited agricultural productivity [13]. The Green Revolution, spearheaded by the introduction of high-yielding wheat varieties and modern agricultural practices, not only alleviated these crises but also laid the foundation for sustained food security. Wheat, as a nutritional powerhouse, emerged as a key driver of this transformation, ensuring caloric adequacy while addressing broader nutritional needs across the region [14]. The success of the Green Revolution in Asia was closely tied to the development and dissemination of improved wheat cultivars. These varieties, developed through advances in agronomy and plant breeding, featured enhanced resistance to diseases, adaptability to diverse agroecological conditions, and higher yield potential. Countries like India and Pakistan witnessed dramatic increases in wheat production, turning from food-deficient to self-sufficient nations within a decade [15]. Wheat's contribution to the daily caloric intake of populations was significant, providing approximately 500 kilocalories per capita daily in major wheat-consuming nations such as India and China [4]. This marked improvement in food availability played a pivotal role in reducing hunger and stabilizing economies.

Beyond its role in addressing caloric deficits, wheat's nutritional value underscores its importance in shaping global food security [16]. As a whole grain, wheat is a rich source of carbohydrates, protein, dietary fiber, and essential micronutrients such as

iron, zinc, and B vitamins. The Green Revolution's focus on wheat not only enhanced the food supply but also provided a platform to combat malnutrition in regions where nutrient deficiencies were prevalent [17]. Wholegrain wheat consumption, in particular, is recognized for its role in mitigating the triple burden of malnutrition—undernutrition, micronutrient deficiencies, and overnutrition—highlighting its relevance in contemporary dietary strategies [18]. The Green Revolution's wheat-centered advancements also had far-reaching implications for agricultural sustainability and economic stability in Asia [19]. Investments in irrigation, fertilizers, and mechanization, combined with the cultivation of high-yielding wheat varieties, improved agricultural productivity and rural livelihoods [20]. These changes enabled millions to escape poverty, as the increased food supply stabilized markets and reduced the risk of food price volatility. However, wheat's dominance in agricultural systems also underscores the need for diversification to ensure resilience against climate change and evolving dietary needs.

2. Nutritional composition

Wheat grains are a rich source of macronutrients, including carbohydrates, proteins, and fats, as well as micronutrients such as vitamins, minerals, and phytochemicals [21]. They also contain total dietary fiber and bioactive compounds. In addition, colored wheat varieties are notable for their natural pigments, such as carotenoids and anthocyanins, which have health-promoting and disease-preventing properties [22]. Carbohydrates, which account for 60–70% of the wheat kernel, are primarily in the form of starch and serve as a major energy source in human diets, making wheat a key component of energy metabolism [23]. Proteins, the second-most abundant macronutrient, constitute about 12–15% of wheat's composition in common varieties [24]. Wheat proteins include gluten, a complex of glutenin and gliadin, which provides the unique elasticity and baking properties essential in bread-making [25]. While wheat is a valuable source of plant-based protein, its amino acid profile is not fully balanced and can be complemented with other foods for a nutritionally complete diet [26]. Fat content in wheat is relatively low, around 2–3%, and primarily concentrated in the germ portion of the kernel. These essential fatty acids contribute to energy and support cellular health [27]. With the global population projected to reach 10 billion by 2050, wheat remains critical for global food security [28]. Advances in wheat breeding for climate resilience, such as varieties tolerant to heat, drought, and pests, are essential to meet rising demands sustainably [29, 30]. Furthermore, promoting wholegrain wheat products can significantly enhance nutritional outcomes, especially in low- and middle-income countries where wheat is a dietary staple. Wheat's role in the Asian Green Revolution highlights its dual significance as a staple crop and a nutritional powerhouse, helping to mitigate food shortages while supporting economic development Van der Ploeg [31]. As global food systems face new challenges, continued research and investment in sustainable wheat production will ensure that its benefits extend to future generations (**Table 1**).

Wheat (*Triticum aestivum*) is a staple cereal grain that provides essential macronutrients, micronutrients, and bioactive compounds contributing to human health. Its nutritional benefits are as follows:

1. *Rich source of carbohydrates*: Wheat is primarily composed of complex carbohydrates, particularly *starch*, which serves as a major energy source. It has a

Sr. no.	Nutritional component	Function in human health	Refs.
1	Carbohydrates	Provide energy for daily activities and bodily functions.	Poole et al. [18]
2	Protein	Essential for muscle repair, growth, and immune function; supports overall cellular processes.	Shiferaw et al. [4]
3	Dietary Fiber	Improves digestive health, regulates blood sugar levels, and reduces the risk of cardiovascular diseases.	Dixon et al. [32]
4	Iron	Prevents anemia, supports oxygen transport in blood, and is critical for cognitive development and physical growth.	FAO [29]
5	Zinc	Boosts immune function, aids wound healing, and supports cellular metabolism and growth.	Shiferaw et al. [4]
6	B vitamins	Vital for energy production, red blood cell formation, and maintaining healthy skin and brain function.	Poole et al. [18]
7	Antioxidants	Protect cells from oxidative damage and lower the risk of chronic diseases such as cancer and diabetes.	FAO [29]
8	Selenium	Strengthens the immune system and supports thyroid function.	Dixon et al. [32]

Table 1.
Nutritional components of wheat and their importance to human health.

low glycemic index when consumed as whole wheat, aiding in sustained energy release and blood glucose regulation (**Table 1**) [33].

2. *Dietary fiber*: Whole wheat is a significant source of *dietary fiber* (10–15% by weight) Shewry and Hey [34]., including insoluble fiber (e.g., cellulose and hemicellulose) and soluble fiber (e.g., beta-glucans) [35]. Fiber supports gastrointestinal health, regulates bowel movements, lowers cholesterol levels, and enhances satiety (**Table 1**) [36].

3. *Protein content*: Wheat provides approximately *10–15% protein*, depending on the variety [37]. It contains *gluten*, a combination of gliadin and glutenin, which is essential for baking properties [38]. Although it is not a complete protein (low in lysine), combining wheat with legumes can compensate for amino acid deficiencies (**Table 1**) [39, 40].

4. *Micronutrients*:

- *Vitamins*: Wheat is a source of *B vitamins* (thiamine, niacin, riboflavin, and folate), which play key roles in energy metabolism, red blood cell formation, and nervous system function [39].
- *Minerals*: It provides essential minerals, like *iron, zinc, magnesium, phosphorus, and selenium*, which are important for oxygen transport, enzyme function, and bone health.

5. *Phytochemicals and antioxidants*: Wheat contains bioactive compounds such as *phenolic acids*, *flavonoids*, and *lignans*, which exhibit antioxidant properties [41]. These compounds reduce oxidative stress, protect against chronic diseases like cardiovascular disease, and have anti-inflammatory effects [42].

6. *Healthy fats*: Though present in small amounts, wheat contains beneficial *polyunsaturated fatty acids (PUFAs)*, including linoleic acid, which supports heart health [43].

7. *Weight management and diabetes control*: Whole wheat products have higher fiber and slower digestion rates, which promote satiety, assist in weight management, and regulate postprandial glucose spikes, making them beneficial for individuals with *diabetes* [44].

8. *Prevention of chronic diseases*: Regular consumption of whole wheat is linked to a reduced risk of *cardiovascular diseases*, *type 2 diabetes*, *obesity*, and certain types of *cancers* (e.g., colorectal cancer) due to its fiber, vitamins, and antioxidant content [45].

3. Agronomic importance and cultivation practices

Wheat (*Triticum aestivum*) offers several agronomic advantages, making it a vital crop for global food security [46]. Its wide adaptability allows it to thrive in diverse agroclimatic conditions, ranging from temperate to semi-arid regions, with a cultivation range spanning latitudes of 30–60° N and 27–40° S [47]. The crop thrives in a variety of agroclimatic zones, including temperate, subtropical, and semi-arid ones, demonstrating its exceptional adaptability. It is a flexible solution for a variety of locations because it can tolerate a large range of temperatures, from cold to hot climes. This versatility enables farmers to cultivate wheat in various soil types, including loamy and clay soils, provided they have good drainage. Wheat has a relatively short growing cycle, maturing within 90–150 days [48], which makes it highly suitable for crop rotation systems. Rotational cropping involving wheat helps in breaking pest and disease cycles, improving soil health, and maintaining soil fertility. Moreover, wheat cultivation enhances land use efficiency as it allows for multiple cropping within a single agricultural year [49].

In terms of climate resilience, wheat exhibits remarkable tolerance to diverse environmental stresses. Modern wheat varieties have been developed to withstand drought, heat, and frost stress, ensuring stable yields in the face of fluctuating climatic conditions. Wheat demonstrates a moderate water-use efficiency, making it suitable for *rainfed agriculture* in arid and semi-arid regions [50]. Under water-limited environments, the deep root system of wheat helps in accessing moisture from lower soil horizons, improving its drought resilience [51]. Additionally, wheat varieties with shorter life cycles can escape terminal drought and heat stress by completing their growth phases before extreme weather events. Breeding programs have further enhanced wheat's resilience by incorporating traits for *salinity tolerance* and resistance to common diseases such as rusts and blights, which are often exacerbated under changing climate scenarios [52]. As a result, wheat remains a crucial crop for ensuring food security in regions prone to climatic variability, offering both agronomic and economic advantages to farmers worldwide (**Table 2**).

Sr. no.	Aspect	Agronomic advantages	Climate resilience benefits	Refs.
1	Adaptability	Grows in diverse agro-climatic zones, including temperate, subtropical, and semi-arid regions.	Tolerates a range of temperatures, from cool to hot climates.	Shoukat et al. [53] and Roy et al. [54]
2	Growing cycle	Short growing period (90–150 days), enabling multiple cropping systems.	Early-maturing varieties can escape terminal drought and heat stress.	Singh et al. [55] and Ghaffar et al. [56]
3	Soil suitability	Thrives in loamy and clay soils with good drainage.	Resilient under varying soil moisture levels.	AbdelRahman et al. [57 and Gooding and Shewry [58]
4	Crop rotation	Breaks pest and disease cycles, improves soil health, and maintains fertility.	Reduces soil degradation and enhances long-term soil sustainability.	Aslam et al. [59]
5	Water efficiency	Moderate water-use efficiency makes it suitable for rainfed agriculture.	Deep root systems improve drought resilience by accessing deeper moisture.	Osman et al. [60] and Lu et al. [61]
6	Stress tolerance	Suitable for low-input farming and marginal lands.	Enhanced resistance to drought, heat, frost, and salinity stress.	Roopnarain et al. [62]
7	Disease resistance	Breeding programs improve resistance to major diseases like rusts and blights.	Reduces yield losses caused by climate-induced pest and disease pressure.	Bhavani et al. [63] and Luo et al. [64]
8	Yield stability	Provides consistent yields across variable conditions.	Climate-resilient varieties ensure stable production under stress.	Bhandari et al. [65] and Ahmad et al. [66]

Table 2.
Wheat's versatility as a crop, its ability to thrive in diverse farming systems, and its resilience to climatic stresses, making it essential for global food security.

4. Role in global food security

Wheat is one of the most vital staple crops worldwide, playing a crucial role in ensuring global food security due to its adaptability, nutritional value, and economic significance. As the second-most cultivated cereal after maize, wheat provides approximately 20% of the global population's caloric and protein intake [67]. This makes it indispensable for meeting the dietary needs of billions, particularly in developing countries. Wheat's ability to thrive in diverse agro-climatic regions contributes to its global accessibility, from temperate zones to semi-arid areas [68]. However, the growing demand for wheat, fueled by population growth and dietary shifts, has placed immense pressure on production systems. According to recent studies, global wheat production must increase by 50% by 2050 to meet projected food demand [69].

Wheat's resilience to environmental stresses is critical for sustaining yields in a changing climate. Advances in breeding for drought- and heat-tolerant wheat varieties have shown promise in mitigating the adverse effects of climate change. However, the increasing frequency of extreme weather events poses challenges to achieving consistent yields, particularly in regions prone to drought, such as Sub-Saharan Africa and South Asia [70]. Furthermore, wheat is a significant source of essential nutrients, including dietary fiber, B vitamins, and minerals like magnesium and zinc, which are vital for combating

malnutrition and micronutrient deficiencies. Fortification programs and biofortified wheat varieties, such as those enriched with zinc, have demonstrated their potential to address hidden hunger in resource-limited populations [71].

Despite its critical role in food security, wheat production faces several challenges, including declining soil fertility, pests, diseases, and unsustainable farming practices. Innovations in precision agriculture, conservation tillage, and integrated pest management are pivotal for enhancing wheat productivity [72] while minimizing environmental degradation [73]. Furthermore, policy interventions and international collaboration are required to stabilize global wheat markets, reduce post-harvest losses, and ensure equitable access to this essential crop. By addressing these challenges and leveraging innovations, wheat can continue to be a cornerstone of global food security in the coming decades (**Figure 1**).

4.1 Global wheat exports

Over the past 5 years, global wheat exports have experienced notable fluctuations due to factors such as production levels, international demand, and geopolitical events. From the 2019/2020 to the 2023/2024 marketing year, wheat exports have increased by approximately 21%, showcasing a consistent upward trend. The global wheat export volume was recorded at 183.6 million metric tons in 2019/2020, rising to 222 million metric tons in the 2023/2024 marketing year [74]. This upward trajectory highlights wheat's growing demand as a staple food for a significant portion of the world's population.

In 2023/2024, US wheat milling hit its lowest level since 2014/2015, and exports dropped to their lowest since 1971, challenged by a strong dollar and Black Sea

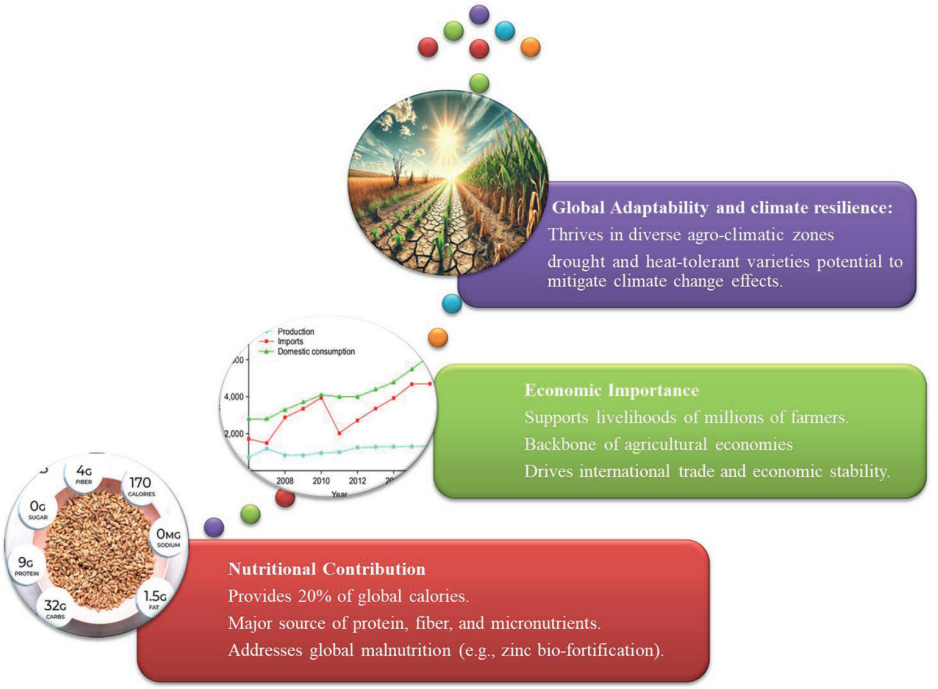


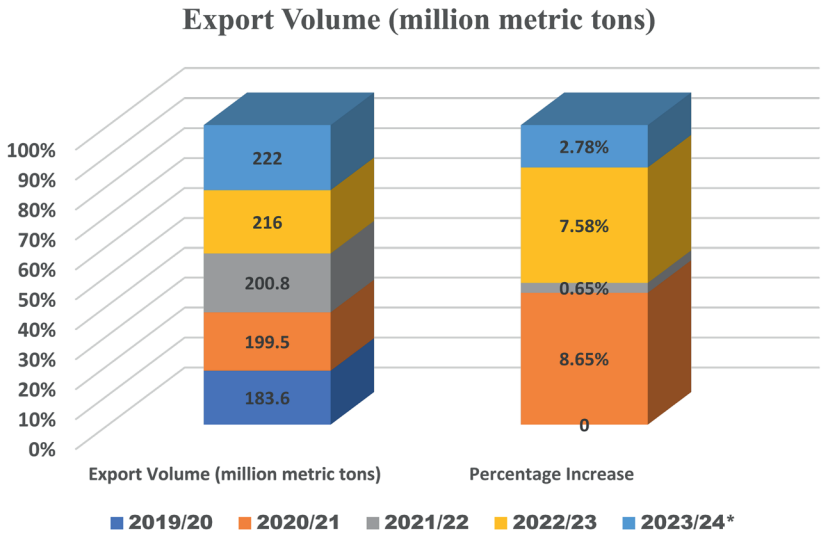
Figure 1.
Importance of wheat in different areas.

competition. However, hot, dry conditions in *Southern Russia* could jeopardize global wheat surpluses, potentially improving US wheat price prospects in 2024/2025 (**Figures 2** and **3**).

4.2 Leading wheat exporting countries (2023/2024)

Russia has emerged as the leading wheat exporter, contributing 51 million metric tons in 2023/2024, followed by the European Union (36.5 million metric tons), Australia (27.5 million metric tons), Canada (26 million metric tons), and the United States (20.5 million metric tons) [74]. These key exporting nations play a significant role in the global wheat market, meeting the food demands of importing countries and ensuring food security worldwide. Wheat is an essential crop, providing about 20% of the world's food calories and protein, making it integral to global diets and nutrition [75].

The economic importance of wheat exports is substantial, contributing significantly to revenue generation, employment, and trade balance. For example, in 2023,



Marketing Year	Export Volume (million metric tons)	Percentage Increase
2019/20	183.6	-
2020/21	199.5	8.65%
2021/22	200.8	0.65%
2022/23	216.0	7.58%
2023/24*	222.0	2.78%

Figure 2.
*Global Wheat Export Volumes (2019/2020–2023/2024). *Projected data for 2023/2024. These figures indicate a consistent upward trend in global wheat exports, with an approximate increase of 21% from the 2019/2020 to the 2023/2024 marketing year.*

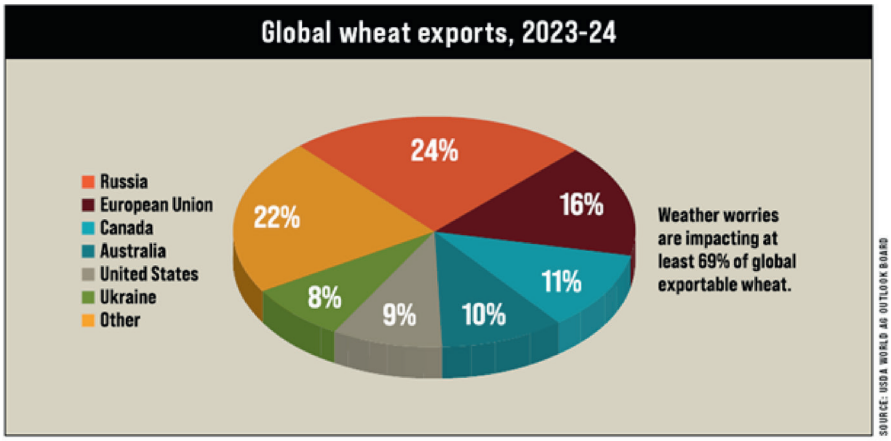


Figure 3.
Global wheat exports in the year of 2023–2024. https://www.farmprogress.com/commentary/wheat-prices-revived-on-weather-woes

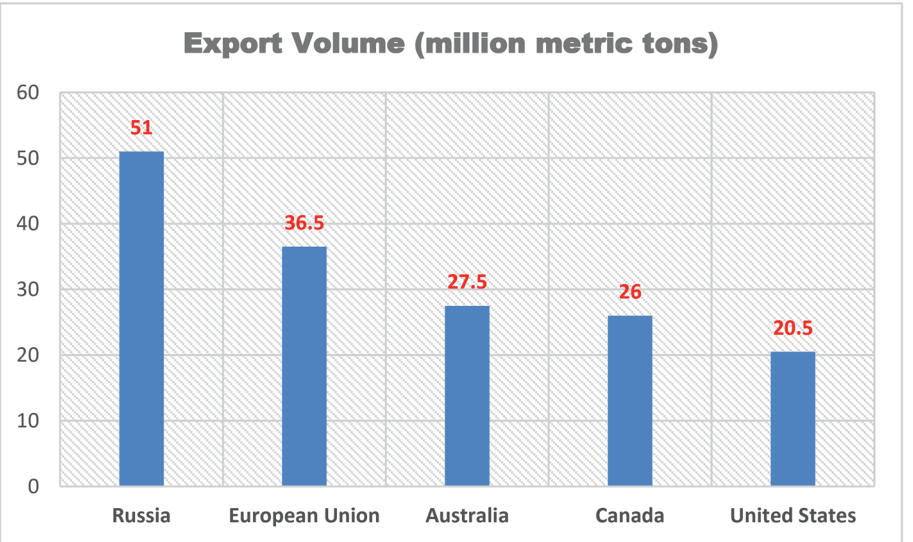
US wheat exports alone were valued at $6.08 billion, with major markets including Mexico, the Philippines, and Japan [76]. The wheat export sector supports employment across the entire supply chain, from farming and processing to logistics and international trade, benefiting both rural and urban economies. Furthermore, wheat exports help maintain favorable trade balances, which are critical for national economic stability. Beyond economic gains, wheat plays a pivotal role in global food security. As an affordable and versatile staple, fluctuations in its prices and supply have far-reaching implications, particularly for developing nations dependent on imports.

In summary, global wheat exports have grown consistently over the past 5 years, with major contributions from Russia, the European Union, and other leading exporters. This growth underscores the importance of wheat in economic development, employment, and food security worldwide, highlighting its critical role in sustaining both global trade and nutrition (**Figure 4**).

4.3 Importance of wheat in economy

Wheat holds a pivotal role in India's economy and sustenance, serving as both a key contributor to agricultural GDP and a cornerstone of food security for its vast population. India is the second-largest producer of wheat globally, with production reaching 112.74 million metric tons in the 2022–2023 season [77], according to the Ministry of Agriculture and Farmers Welfare [78, 79]. This extensive production not only meets domestic consumption needs but also bolsters global food supplies, positioning India as a significant player in the international wheat market. In recent years, India has emerged as a notable exporter, with shipments reaching new markets, particularly during disruptions in global supply chains caused by geopolitical tensions, such as the Russia-Ukraine conflict [80]. Wheat exports from India crossed 8.5 million tons in 2021–2022, as per government reports, highlighting its growing importance in stabilizing global food security [81].

The economic importance of wheat is further underscored by its impact on rural livelihoods, nearly 80% of India's farmers are smallholders, and wheat cultivation



Country	Export Volume (million metric tons)	Percentage Share
Russia	51.0	31.57%
European Union	36.5	22.59%
Australia	27.5	17.02%
Canada	26.0	16.09%
United States	20.5	12.69%

Figure 4.
Export of wheat in different countries in million metric tons.

serves as a primary or supplementary source of income for millions of these households [82]. The crop's high adaptability to diverse agro-climatic zones ensures its widespread cultivation, particularly in states like Punjab, Haryana, Uttar Pradesh, and Madhya Pradesh, which are the backbone of India's Green Revolution [83]. It has been found that the wheat's short growth season (90–150 days) allows for a range of cropping techniques, and early-maturing varieties may tolerate terminal drought and heat stress. It is resilient to a variety of soil moisture levels and grows best on clay and loamy soils with sufficient drainage. Its role in crop rotation also helps maintain fertility, improves soil health, decreases soil degradation, breaks pest and disease cycles, and boosts long-term soil sustainability (**Table 2**). The crop is appropriate for rainfed agriculture because of its moderate water-use efficiency. By gaining access to deeper moisture, its deep root systems increase drought resilience and strengthen its resistance to dry circumstances. With improved resilience to climatic stresses like drought, heat, frost, and salinity, it is especially well-suited for low-input farming and marginal soils. Breeding initiatives have greatly increased disease resistance, bolstering the crop's resistance to important diseases like rusts and blights. This, in turn, lowers production losses brought on by pest and disease pressures brought on by climate change. The crop's importance in sustainable agriculture is further supported by the fact that it guarantees steady yields under a variety of circumstances and that climate-resilient cultivars help maintain production even in the face of stress (**Table 2**). A significant portion of the rural population is dependent on wheat for employment,

whether directly through farming or indirectly through supply chain activities such as transportation, storage, and processing. Moreover, the Public Distribution System (PDS) heavily relies on wheat as a staple, making it a critical element in government efforts to ensure food security and alleviate poverty.

Research highlights the critical role of wheat in mitigating hunger and supporting nutritional needs in a country where 14% of the population is still undernourished [84]. Wheat-based products contribute to nearly 50% of the caloric intake of an average Indian diet, especially in northern and central regions. Furthermore, the adoption of high-yielding varieties and modern agricultural practices has enhanced productivity, helping to stabilize food prices and contribute to economic resilience. However, challenges such as climate change, water resource constraints, and fluctuating international demand pose risks to the sustainability of wheat production. Recent studies emphasize the need for policy interventions, such as incentivizing climate-resilient farming practices and improving infrastructure, to safeguard wheat's role in the economy and global food systems. In conclusion, wheat's significance extends beyond its economic contributions to embody a lifeline for millions of Indians, both as a source of livelihood and nutrition. With strategic advancements in technology, policy, and global trade relations, wheat can continue to underpin India's agricultural strength while supporting international food security.

In 2023/2024, global wheat utilization is forecast to rise to 789.5 million tons, driven by increased food consumption in Asia and Africa [85], and higher feed use in China. Wheat inventories are expected to remain near record levels at 315 million tons, with a rise in stocks in Ukraine and the United States [86]. Global wheat trade is predicted to decline to *194.4 million tons*, mainly due to reduced imports by the *EU and Türkiye* and smaller exports from *Australia*, *Canada*, and *Ukraine* [87]. However, *Russia* and *Argentina* are expected to increase their exports, with Russia solidifying its position as the world's largest wheat exporter (**Figure 5**).

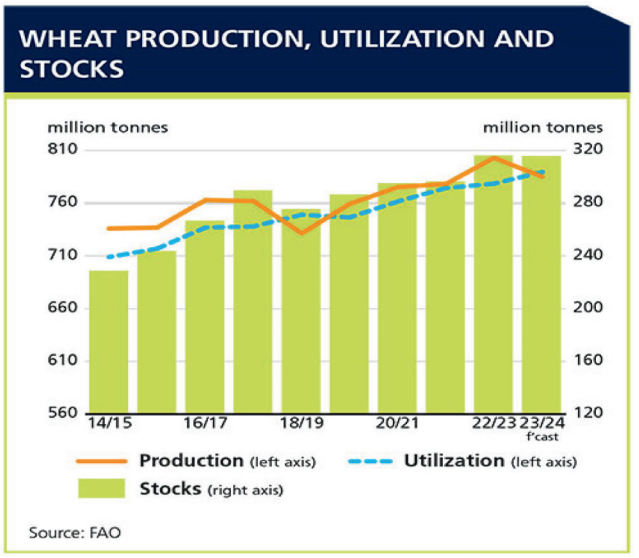


Figure 5.
Wheat production utilization and stocks. https://millermagazine.com/blog/global-wheat-production-fall-in-2023-still-second-highest-ever-5465

4.4 Challenges and opportunities

One of the primary challenges lies in the *declining nutritional quality* of wheat due to intensive farming practices and genetic modifications aimed at increasing yield rather than nutrient density [88]. Modern wheat varieties often exhibit reduced levels of essential micronutrients like *zinc*, *iron*, and *selenium*, leading to widespread micronutrient deficiencies, particularly in developing regions [89]. Additionally, wheat's dependence on synthetic inputs, such as fertilizers and pesticides, has raised environmental concerns while exacerbating soil degradation and loss of biodiversity. Climate change poses further threats, with rising temperatures, droughts, and salinity reducing both yield and grain quality [90]. The prevalence of *gluten intolerance* and celiac disease among certain populations also diminishes wheat's nutritional appeal, creating a need for alternatives or improved wheat varieties [91].

Despite these challenges, wheat offers substantial opportunities to address malnutrition and food security through *biofortification* and sustainable agricultural practices. Biofortified wheat varieties, enhanced with higher levels of *zinc*, *iron*, and *protein*, have already shown promise in combating hidden hunger in vulnerable populations [92]. Advancements in *genomic breeding* and CRISPR technology can further improve wheat's nutritional profile, drought resistance, and resilience to abiotic stresses like heat and salinity [46]. Promoting *whole wheat consumption* rather than refined products can help maximize its dietary fiber, vitamins, and antioxidants, contributing to better gastrointestinal health and reduced risks of chronic diseases such as diabetes and cardiovascular ailments.

Wheat also has the potential to address global food security through *climate-resilient cultivation techniques*, such as precision agriculture, water-efficient irrigation, and crop rotation systems [93]. Strengthening policies that encourage wheat diversification and value addition, such as fortification with micronutrients and the development of gluten-free alternatives, can expand its nutritional accessibility to a broader consumer base. Moreover, wheat-based innovations in *functional foods* and health-promoting products offer opportunities to meet the growing demand for nutritionally enriched and sustainable food solutions. In conclusion, addressing the challenges of declining nutrient content, environmental sustainability, and health-related concerns will require an integrated approach involving *innovative breeding*, *sustainable farming practices*, and *value chain enhancements*. By leveraging these opportunities, wheat can be transformed into a powerful tool to combat malnutrition and shape global food security in an equitable and resilient manner.

4.5 Conclusion

Wheat stands as a cornerstone of global food security due to its significant role in nutrition, agriculture, and economic stability. As a dietary staple for over a third of the global population, wheat provides essential macronutrients, micronutrients, and dietary fiber, addressing both caloric needs and micronutrient deficiencies. Its adaptability to diverse agro-climatic regions and agronomic advantages have made it a resilient crop in the face of climate variability, ensuring food supply in vulnerable regions. Furthermore, wheat's contributions to rural livelihoods, international trade, and economic development highlight its broader socioeconomic importance.

However, challenges such as declining nutrient density, climate change, soil degradation, and the rise of dietary concerns like gluten intolerance necessitate a multi-faceted approach to wheat production and consumption. Innovations in biofortification,

sustainable cultivation practices, and climate-resilient breeding offer promising solutions to enhance wheat's role in addressing hidden hunger and ensuring global food security. Policies promoting whole grain consumption and reducing post-harvest losses are critical to maximizing wheat's nutritional and economic potential.

In conclusion, through integrated efforts in research, technology, and policy, wheat can continue to serve as a vital crop for nourishing populations and supporting resilient food systems worldwide, even amid evolving challenges.

5. Conclusion

In conclusion, wheat is a staple of global food security and a nutritional powerhouse, providing a wealth of macronutrients, micronutrients, and chemicals that promote health. It is essential to millions of livelihoods and national economies because of its extensive cultivation and economic significance. But maintaining its crucial function in the face of environmental difficulties, soil erosion, and new health issues calls for creative solutions. For future generations to have a robust and nourishing supply of wheat, biofortification, climate-resilient crop types, and sustainable agriculture methods are essential. To fully utilize wheat's potential in tackling poverty, malnutrition, and the changing needs of a growing world population, strategic investments and supportive policies will be essential.

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