

Pulses for Sustainable Development and Food Security: A Review of Their Role in Nutrition, Agriculture, and Rural Livelihoods

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Abstract:

Pulses play a crucial role in achieving global food and nutrition security, particularly among low-income and marginalized populations. Due to their affordability, nutritional content, and adaptability to harsh environments, pulses are recognized as vital alternatives to animal-based protein. This paper reviews the multifaceted contributions of pulses to sustainable development, focusing on their role in alleviating protein and iron deficiencies, supporting rural livelihoods, enhancing agricultural sustainability, and addressing food security challenges. These pulses are rich in plant-based protein (17–30% dry weight), dietary fiber (8 g/100 g cooked), iron (2.9–3.3 mg/100 g), and other micronutrients, pulses serve as cost-effective and sustainable alternatives to animal protein. Globally, pulse cultivation has expanded from 64 million hectares in 1970 to over 93 million hectares in 2019, with production rising to approximately 92 million tones. India remains the largest producer, contributing around 27% of the global output. Beyond nutrition, pulses contribute to sustainable agriculture through biological nitrogen fixation, improved soil structure, and reduced dependency on synthetic fertilizers cutting nitrogen use by nearly 37% in rotational systems. Their resilience to drought and low-input requirements make them suitable for marginal lands and climate-smart agriculture. It further emphasizes the urgent need for investment in pulse research, post-harvest infrastructure, and farmer training to scale up production, improve storage and value addition, and ensure long-term food system resilience

Keywords Pulses, Food security, Resilience, Micronutrients

1. Introduction

Food and nutrition security remains one of the greatest global challenges of the Ensuring 21st century. According to the Food and Agriculture Organization (FAO, 2012), over 820 million people worldwide are chronically undernourished, with the highest prevalence occurring in low- and middle-income countries. Malnutrition encompasses not only energy deficiency but also a lack of essential macronutrients and micronutrients necessary for growth, development, and overall health. Among the various forms of malnutrition, protein-energy undernutrition and micronutrient deficiencies particularly iron deficiency anemia—continue to be pervasive, affecting billions globally and contributing significantly to child morbidity, mortality, stunted growth, and impaired cognitive development (Smith & Haddad, 2015; Black et al., 2013). This crisis underscores the urgent need to diversify global food systems beyond staple grains and improve access to affordable, nutrient-rich foods.

Animal-based proteins such as meat, eggs, dairy products, and fish are typically considered superior sources of high-quality protein and bioavailable micronutrients. However, these foods are often inaccessible to economically disadvantaged populations due to their high costs, cultural barriers, and environmental constraints associated with livestock production (Gómez &

Ricketts, 2013; Popkin, 2014). This has led to a heavy reliance on cereals and starchy staples, which, while providing calories, lack sufficient protein quality, essential amino acids, and micronutrients required for optimal nutrition (Pingali, 2007; Keats & Wiggins, 2014). As the global population is projected to reach nearly 10 billion by 2050, the challenge of meeting protein needs sustainably without exacerbating environmental degradation becomes even more pressing (The Government Office for Science, 2011; Gregory et al., 2005).

Pulses, a subgroup of legumes harvested for dry seeds including lentils (*Lens culinaris*), chickpeas (*Cicer arietinum*), dry beans (*Phaseolus vulgaris*), pigeon peas (*Cajanus cajan*), cowpeas (*Vigna unguiculata*), and others have gained increasing recognition as a cornerstone in addressing these global nutrition challenges. These crops are inherently nutrient-dense, providing approximately 17–30% protein by dry weight, complex carbohydrates, and significant amounts of dietary fiber, iron (2.9–3.3 mg/100 g cooked), folate, magnesium, and other essential micronutrients (Ha et al., 2014; Petry et al., 2015; Sievenpiper et al., 2009). Regular consumption of pulses has been linked to reduced risks of cardiovascular diseases, improved glycemic control, and prevention of obesity and hypertension (Jayalath et al., 2014; Kim et al., 2016). Moreover, initiatives in biofortification have demonstrated the potential of pulses, such as iron-rich bean varieties, to combat anemia and micronutrient deficiencies in vulnerable populations (Haas et al., 2016).

Beyond their nutritional profile, pulses offer substantial agronomic and environmental benefits. Unlike most cereal crops, pulses form symbiotic associations with *Rhizobium* bacteria in their root nodules, enabling biological nitrogen fixation that enriches soil fertility and reduces dependence on synthetic fertilizers (Peoples et al., 2015; Van Kessel & Hartley, 2000). This ecological service contributes to sustainable cropping systems, lowering greenhouse gas emissions associated with fertilizer production and application (Lemke et al., 2007). Pulses are also highly adaptable to diverse agroecological zones, thriving in drought-prone and low-input farming systems where other crops may fail (Kissinger, 2016; Grace et al., 2003). Given the increasing frequency of climate-related shocks, incorporating pulses into agricultural production is essential for building climate-resilient food systems (Gregory et al., 2005; FAO, 2016).

Economically, pulses are vital for the livelihoods of millions of smallholder farmers, particularly in South Asia and Sub-Saharan Africa. India, for example, contributes around 27% of global pulse production, providing a primary source of protein for its largely vegetarian population (Joshi & Rao, 2016; Singh, Shahi & Singh, 2016). Pulse cultivation not only provides household food security but also generates income, enhances crop diversification, and reduces vulnerability to market fluctuations in staple cereal crops (World Bank, 2008; Quisumbing et al., 2015). However, despite their importance, global pulse production has not kept pace with growing demand, leading to reliance on imports and price volatility in several regions (Singh et al., 2013; FAO, 2014).

Furthermore, the current global food system remains heavily skewed toward a few staple grains, with inadequate investment in pulse research, infrastructure, and market development (Webb, 2013; Ruel et al., 2013). Constraints in post-harvest handling, storage, and processing lead to significant losses, reducing availability and affordability for consumers (Mensah & Tomkins, 2003). Addressing these systemic gaps is crucial for enhancing the role of pulses in sustainable diets and achieving multiple Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), and SDG 13 (Climate Action).

Given their multiple benefits spanning nutrition, agriculture, environment, and rural livelihoods, pulses are emerging as a vital component of future food systems. They present a unique opportunity to address malnutrition sustainably, diversify agricultural production, and mitigate environmental impacts of protein supply chains. This paper aims to provide a comprehensive review of the role of pulses in promoting food and nutrition security, sustainable agricultural practices, and rural economic development. It further highlights challenges, research gaps, and potential strategies to scale up pulse production and consumption globally, thereby contributing to more resilient and equitable food systems for the future.

2. The Nutritional Importance of Pulses

Pulses, including lentils (*Lens culinaris*), chickpeas (*Cicer arietinum*), beans (*Phaseolus vulgaris*), and peas (*Pisum sativum*), are nutrient-dense plant-based foods that play a crucial role in addressing global nutrition challenges, particularly in low- and middle-income countries where access to animal-source foods is limited (FAO, 2016). These legumes provide an affordable and sustainable solution to protein-energy malnutrition and micronutrient deficiencies, offering 17–30% protein by dry weight, considerably higher than most cereals, making them vital in improving dietary protein intake in populations relying heavily on staple grains (Havemeier et al., 2017). A 100-gram serving of cooked lentils delivers approximately 9 grams of protein, 20 grams of complex carbohydrates, and 8 grams of dietary fiber, with a very low-fat content (Boeck, 2021). Pulses also contain a rich profile of essential amino acids, particularly lysine, which complements cereal-based diets deficient in this amino acid, thereby enhancing overall protein quality (Singh et al., 2013).

Beyond their protein content, pulses are an important source of key micronutrients. Cooked chickpeas provide 2.9 mg of iron, 291 mg of potassium, and 1.3 mg of zinc per 100 grams, while lentils contain up to 3.3 mg of iron and 369 mg of potassium, both critical for preventing anemia and supporting cardiovascular health (Boeck, 2021). Although the non-heme iron in pulses is less bioavailable than animal-derived iron, its absorption can be significantly improved when consumed with vitamin C-rich foods, helping to combat widespread iron deficiency anemia, particularly among women and children (Black et al., 2013).

Regular pulse consumption is associated with improved glycemic control due to their low glycemic index (29–48), high resistant starch content, and ability to modulate blood glucose levels, which makes them beneficial in preventing and managing type 2 diabetes (FAO, 2016). In addition, pulses contain bioactive compounds such as polyphenols, saponins, and flavonoids, known for their antioxidant, anti-inflammatory, and lipid-lowering effects, further enhancing their protective role against chronic non-communicable diseases (Ha et al., 2014; Havemeier et al., 2017).

Given their affordability, nutrient density, and environmental sustainability, pulses are indispensable in global nutrition strategies. Their inclusion in public feeding programs, social safety nets, and household diets has been shown to improve dietary diversity and nutritional adequacy (Chakrabarti et al., 2016). Moreover, their agronomic benefits, including biological nitrogen fixation, contribute to soil fertility and sustainable agricultural systems, enhancing long-term food security while mitigating greenhouse gas emissions (Lemke et al., 2007; Peoples et al., 2015). Therefore, promoting pulse consumption at both policy and community levels represents a cost-effective and sustainable approach to addressing undernutrition, reducing micronutrient deficiencies, and supporting planetary health simultaneously (FAO, 2016; Singh et al., 2016).

3. Pulses and Food Security

Pulses are nutrient-dense leguminous crops that play a crucial role in global food and nutritional security. They are rich sources of plant-based proteins, complex carbohydrates, dietary fiber, and essential micronutrients such as iron, zinc, and folate, making them vital in addressing malnutrition, especially in developing countries (FAO, 2016). Beyond their nutritional benefits, pulses contribute to sustainable agricultural systems through biological nitrogen fixation, improving soil health and reducing the need for synthetic fertilizers, which in turn lowers greenhouse gas emissions (Lemke et al., 2007; Van Kessel & Hartley, 2000).

The global demand for food is expected to increase significantly due to population growth, urbanization, and changing dietary preferences (United Nations, 2014). However, agricultural production faces constraints from limited arable land, climate change impacts, and declining soil fertility (Gregory et al., 2005). Pulses offer a sustainable solution by enhancing cropping system diversity, improving soil nutrient balance, and providing climate resilience to farming systems (Peoples et al., 2015).

In India, pulses are particularly critical for ensuring food and nutritional security for low-income populations who largely depend on plant-based protein sources (Singh et al., 2016). Despite their importance, pulse production has often lagged behind demand due to factors like low yields, limited investment in research, and inadequate policy support (Singh et al., 2013). Scaling up pulse production, improving value chains, and investing in biofortified pulse varieties are essential strategies to meet future food requirements and address micronutrient deficiencies globally (Haas et al., 2016).

Thus, pulses represent a sustainable, low-cost, and nutrient-rich solution to tackle food insecurity, improve dietary quality, and support environmental sustainability. Policy interventions, technological innovations, and enhanced farmer support systems are necessary to maximize their role in feeding the growing population.

4. Agricultural and Environmental Benefits of Pulses

Agriculture is fundamental to ensuring global food security, and pulses play a crucial role in enhancing the sustainability of agricultural systems. Over the last five decades, pulse cultivation worldwide has grown substantially, with the cultivated area increasing from 64 million hectares in 1970 to 93 million hectares in 2019, global production rising from 42 to 92 million tonnes, and yields improving to nearly 994 kg/ha (Joshi & Rao, 2023).

Pulses such as lentils, chickpeas, and field peas contribute significantly to soil health through their ability to fix atmospheric nitrogen in association with symbiotic bacteria, thereby reducing the need for synthetic nitrogen fertilizers and minimizing greenhouse gas emissions (Lemke et al., 2007; Van Kessel & Hartley, 2000). Their deep-rooting systems improve soil structure and organic carbon content, enhancing nutrient cycling and water-use efficiency, which is particularly important in rainfed and resource-limited environments (Ali et al., 2022).

In India, which accounts for about 27% of global pulse production, pulse-based cropping systems have been shown to enhance soil organic matter and overall farm profitability, making them a key component of sustainable agricultural practices (Singh et al., 2021). Furthermore, many pulses such as cowpeas and pigeon peas exhibit high drought tolerance, making them reliable crops in arid and semi-arid climates, thereby supporting food production even under water scarcity (Peoples et al., 2015). Their inclusion in crop rotations disrupts pest and disease cycles, reduces dependency on chemical inputs, and supports biodiversity, leading to more resilient and climate-smart farming systems globally (Singh et al., 2013). By improving soil

fertility, optimizing resource utilization, and providing climate resilience, pulses contribute not only to environmental conservation but also to long-term agricultural productivity and food security worldwide.

5. Post-Harvest Storage and Shelf Life of Pulses

Pulses are an essential source of nutrition and play a critical role in global food security, particularly in developing regions where they are a primary protein source. One of their significant advantages is their relatively long shelf life, which makes them highly suitable for storage and distribution in areas with limited access to refrigeration and modern preservation technologies. Traditionally, pulses are dried to low moisture levels (around 10–12%) and stored in well-ventilated, dry, and cool areas to reduce the risk of microbial growth and spoilage (Reddy et al., 2017).

However, despite these advantages, post-harvest storage faces challenges such as insect infestation, mold development under high humidity, and quality deterioration due to improper handling and lack of scientific storage methods (Kumar et al., 2019). Studies have highlighted that the primary factors affecting the shelf life of pulses include grain moisture content, temperature fluctuations, oxygen exposure, and inadequate protection from pests (Manandhar et al., 2018).

Modern approaches, such as hermetic storage technologies that use airtight containers to limit oxygen availability, have shown promising results in reducing post-harvest losses and maintaining nutritional quality (Baoua et al., 2012). Similarly, solar drying has emerged as a sustainable method to achieve safe moisture levels rapidly, reducing the risk of fungal contamination in humid environments (Stathers et al., 2020).

Establishing community grain banks equipped with scientific storage facilities has also been recognized as an effective way to ensure year-round availability of safe and good-quality pulses, particularly in rural and resource-limited areas (FAO, 2016). Therefore, while traditional practices have contributed to the natural longevity of pulses, scaling up improved post-harvest handling and storage technologies is essential to minimize losses, maintain nutritional quality, and strengthen food security globally.

6. Challenges and Knowledge Gaps in Pulses Production and Utilization

Despite their recognized nutritional and environmental benefits, several challenges hinder the optimal production, consumption, and utilization of pulses globally. One of the primary issues is the limited access to quality seeds and essential agricultural inputs such as biofertilizers and pest-resistant varieties, which restrict productivity gains (Reddy et al., 2017). Additionally, there remains a lack of widespread awareness about the high protein content, micronutrient richness, and health-promoting properties of pulses among consumers, especially in urban populations shifting toward processed and cereal-dominated diets (Joshi & Parthasarathy Rao, 2016).

Inadequate extension services and poor dissemination of improved agronomic practices, post-harvest handling techniques, and modern storage solutions further contribute to significant post-harvest losses, reducing both the availability and market value of pulses (Kumar et al., 2019). Moreover, the underrepresentation of pulses in national food and nutrition policies, compared to major cereals like wheat and rice, has resulted in low public investment and insufficient incentives for farmers to adopt pulse-based cropping systems (Pingali, 2015).

A lack of structured procurement and price support mechanisms in many countries discourages farmers from expanding cultivation despite increasing demand (FAO, 2016).

Addressing these challenges requires multi-level interventions, including farmer training, provision of high-quality inputs, establishment of community-level storage facilities, and stronger policy frameworks that integrate pulses into government food security and nutrition programs. Bridging these knowledge gaps and improving value-chain linkages will not only enhance pulse production but also ensure their wider accessibility and affordability, thereby contributing to global nutrition security and sustainable agricultural development.

7. Future Directions and Strategic Recommendations

Maximizing the potential of pulses in global food and nutrition systems requires a comprehensive and integrated strategy. Raising public awareness about the nutritional, economic, and environmental benefits of pulses is essential to increase their acceptance and consumption (FAO, 2016). Strengthening agricultural extension services can bridge knowledge gaps, providing farmers with improved cultivation practices, pest and disease management techniques, and modern post-harvest solutions (Kumar et al., 2019).

Further investment in research and development (R&D) is crucial to develop high-yielding, pest-resistant, and climate-resilient pulse varieties that enhance productivity and profitability (Reddy et al., 2017). Incorporating pulses into national food security programs, including school meals, public distribution systems, and maternal and child health initiatives, can help address protein-energy malnutrition and micronutrient deficiencies (Pingali, 2015). Additionally, empowering women farmers through training, credit access, and market linkages can improve production efficiency and livelihoods, given their significant role in pulse cultivation (Quisumbing et al., 2015).

A multi-sectoral approach involving policymakers, research institutions, private stakeholders, and farming communities is vital to overcome current production and utilization barriers. Scaling up pulse integration in agricultural systems not only enhances food and nutrition security but also supports climate resilience and sustainable resource management globally.

8. Conclusion

Pulses occupy a central position in building resilient and sustainable food systems worldwide. As nutrient-dense plant-based proteins, they serve as a cost-effective solution to malnutrition, especially in low- and middle-income countries where access to animal protein sources is limited (FAO, 2016). Their high content of essential amino acids, dietary fiber, vitamins, and minerals contributes significantly to improved dietary quality and overall public health (Ha et al., 2014). Furthermore, the low glycemic index of pulses supports the management and prevention of non-communicable diseases such as diabetes, cardiovascular diseases, and obesity, making them vital for addressing the global burden of diet-related illnesses (Imamura et al., 2015).

Beyond their nutritional value, pulses play a pivotal role in ecological sustainability. Their ability to fix atmospheric nitrogen naturally reduces dependency on synthetic fertilizers, thereby lowering greenhouse gas emissions and mitigating environmental degradation (Lemke et al., 2007). Pulse-based cropping systems enhance soil health, biodiversity, and water-use efficiency, making them crucial for climate-resilient agriculture (Van Kessel & Hartley, 2000). By improving farm profitability and ensuring better yields under marginal conditions, pulses also contribute to poverty alleviation and improved livelihoods, particularly among smallholder and women farmers (Quisumbing et al., 2015).

Despite these advantages, the global potential of pulses remains underutilized due to limited consumer awareness, lack of policy support, and inadequate post-harvest infrastructure (Singh et al., 2016). To meet the United Nations Sustainable Development Goals (SDGs)—notably SDG 2 (Zero Hunger) and SDG 13 (Climate Action)—it is essential to prioritize pulses in agricultural research, nutrition programs, and food security policies. Strengthening value chains, supporting innovation in pulse-based food products, and fostering global campaigns to increase their consumption can help overcome current barriers.

In conclusion, pulses offer a triple-win solution: they improve human health, promote environmental sustainability, and enhance economic resilience of farming communities. Scaling up their production and consumption is not just an agricultural intervention but a global necessity to achieve food security and climate-smart development in the coming decades.

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