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Pulses: A Nutritional Resource and a Natural Ally of Soil Health

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Abstract

Pulses occupy a unique position in sustainable food and farming systems because they contribute to both human nutrition and soil health. Chickpea, pigeonpea, lentil, mungbean, blackgram and other grain legumes are important sources of plant protein, dietary fibre, minerals and vitamins. Their nutritional contribution is particularly relevant in cereal-dominated diets and resource-constrained regions. At the same time, pulse crops form symbiotic associations with nitrogen-fixing microorganisms, enabling biological nitrogen fixation and contributing to nutrient cycling. When incorporated into crop rotations, intercropping and conservation-oriented farming systems, pulses can improve soil organic matter, microbial activity, nutrient-use efficiency and resource conservation. Their adaptability to rainfed environments further strengthens their role in climate-resilient agriculture. Thus, pulses can contribute simultaneously to nutritional security, soil restoration and sustainable agricultural production.

Keywords: Biological nitrogen fixation, Human nutrition, Pulses, Soil health, Sustainable agriculture

Introduction

Pulses have been part of human diets and agricultural systems for centuries. Chickpea, pigeonpea, lentil, mungbean, blackgram, cowpea and related grain legumes are cultivated across diverse environments, from relatively fertile irrigated lands to rainfed and marginal agroecosystems. Their importance has traditionally been associated with food and nutrition, but their contribution to agricultural sustainability is equally significant.

Modern agriculture is increasingly confronted with a difficult combination of challenge, *viz.* soil degradation, declining resource-use efficiency, climate variability, increasing production costs and the need to produce nutritious food from limited land and water resources. Intensive cereal-based systems, although highly productive, can place considerable pressure on soil and other natural resources when diversification and nutrient management are inadequate. In this context, pulses have gained renewed attention as multifunctional crops capable of contributing simultaneously to food security, soil fertility and environmental sustainability (Kumar *et al.*, 2023; Kumar *et al.*, 2026).

The importance of pulses therefore extends beyond the harvested grain. In a broader food-system context, the importance of pulses extends from production and soil management to processing, markets, consumption and nutrition. Their potential contribution to healthier and more sustainable diets therefore depends not only on increasing production, but also on improving the efficiency of pulse value chains and creating conditions that encourage their wider consumption (McDermott and Wyatt, 2017). Their value can be understood through two closely connected pathways: what pulses provide to people and what pulse plants return to the farming system.

Pulses as a Source of Nutritional Security

Pulses are among the most important plant-based sources of dietary protein. Most commonly consumed pulses contain approximately 20-25% protein, although considerable variation occurs among crops and varieties. For example, protein concentration may range from about 16-28% in chickpea, 19-32% in lentil, 21-31% in mungbean and 16-24% in pigeonpea (Jukanti *et al.*, 2012) (Table 1). This variation

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provides considerable scope for nutritional improvement through crop and varietal diversification.

Table 1: Major nutritional contributions of pulses to human diets

Nutritional component	Contribution of pulses
Protein	Generally about 20-25% in many commonly consumed pulses.
Dietary fibre	Important source of both soluble and insoluble dietary fibre.
Iron	Valuable plant-based source, particularly in cereal-dominated diets.
Zinc	Contributes to dietary Zn supply.
Minerals	Provides potassium, phosphorus, calcium and magnesium.
Vitamins	Important source of B-group vitamins and folates.
Dietary role	Complements cereals and improves the nutritional diversity of meals.

[Source: Jukanti *et al*. (2012); Ranjith and Sridevi (2021); Kumar *et al*. (2023)]

The nutritional value of pulses, however, is not limited to protein. Pulse seeds also supply dietary fibre, iron, zinc, potassium, phosphorus, calcium, magnesium and B-group vitamins. Their contribution becomes particularly important in cereal-dominated diets, where cereals and pulses provide complementary amino acid profiles. Their traditional combination can therefore improve the overall nutritional quality and diversity of meals (Jukanti *et al.*, 2012; McDermott and Wyatt, 2017).

Pulses also have an important place in dietary patterns associated with long-term health. Their fibre-rich composition and relatively favourable nutritional profile make them useful components of balanced diets. Regular consumption of pulses has been associated with dietary patterns that may help reduce the risk of obesity, cardiovascular disease and type-2 diabetes (Mudryj *et al.*, 2014; Ranjith and Sridevi, 2021). Such benefits are especially relevant as food systems increasingly need to address both undernutrition and diet-related chronic diseases.

Despite these advantages, pulse consumption remains relatively low at the global level. Kumar *et al.* (2023) reported that the global average protein supply from pulses was only about 4.2 g per capita per day, accounting for a relatively small proportion of total protein supplied from both plant and animal sources. This indicates that pulses remain underutilised in many food systems despite their nutritional potential.

The nutritional contribution of pulses is especially important in rainfed farming communities, where households may depend heavily on crops produced within their own farms. In such settings, pulse cultivation can provide a relatively affordable source of protein while contributing to household food diversity. Kumar *et al.* (2023) emphasised that pulses are particularly valuable in rainfed agroecosystems because they can contribute to both nutritional and livelihood security under resource-constrained conditions.

The Biological Advantage of Pulse Crops

What makes pulses different from most cereal crops is their relationship with soil microorganisms. Pulse plants form symbiotic associations with nitrogen-fixing bacteria in root nodules. Through biological nitrogen fixation, atmospheric nitrogen is converted into forms that can be incorporated into plant biomass (Figure 1).

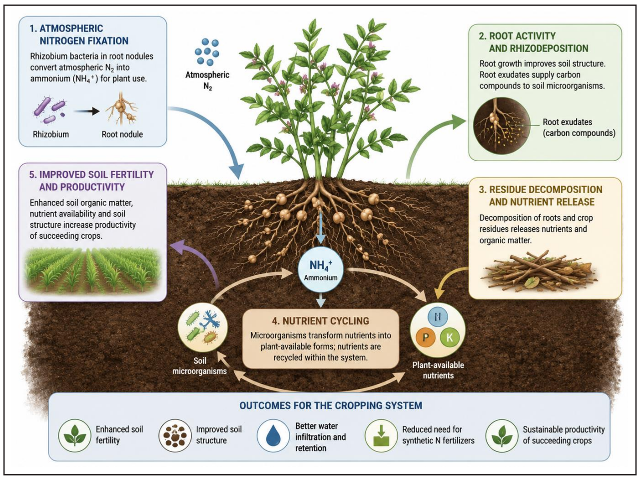

Figure 1: Pulse crops linking atmospheric nitrogen fixation, root activity and nutrient cycling for soil fertility and productivity

Depending on crop species, soil properties and environmental conditions, pulse crops can contribute approximately 30-300 kg N $ha^{-1}year^{-1}$ through biological nitrogen fixation (Kumar *et al.*, 2026). This fixed nitrogen is not necessarily available immediately to the succeeding crop, because a substantial proportion remains in plant biomass, roots and residues. As these materials decompose, nitrogen is progressively returned to the soil and becomes part of the nutrient-cycling process (Kumar *et al.*, 2026). Pulses therefore contribute to soil fertility not only through biological nitrogen fixation but also through leaf fall, root residues and other organic inputs (Ranjith and Sridevi, 2021; Kumar *et al.*, 2026).

This biological process has major significance for agricultural sustainability. Synthetic nitrogen fertilisers are energy-intensive to manufacture and their inefficient use can contribute to greenhouse gas emissions and nutrient losses. Incorporating pulses into cropping systems can therefore reduce dependence on externally supplied nitrogen and improve the biological efficiency of nutrient management (Kumar *et al.*, 2026).

Pulses and Soil Health

Healthy soil is much more than a reservoir of plant nutrients. It is a living system in which organic matter, microorganisms, roots, minerals, water and air interact continuously. Pulse crops influence several of these components through their roots, residues and association with soil microorganisms.

Pulse residues are relatively rich in nitrogen compared with many cereal residues and provide substrates for microbial activity. Root exudates and rhizodeposition also supply carbon compounds to the rhizosphere. These inputs can stimulate microbial processes involved in decomposition and nutrient transformation, thereby supporting soil biological functioning (Kumar *et al.*, 2026). The pulse rhizosphere may also provide a more biologically active environment, with microbial activity contributing to improved soil aggregation and structure (Ranjith and Sridevi, 2021).

Root growth and organic inputs can favour soil aggregation, while biologically active rhizospheres contribute to the formation and stabilisation of soil aggregates. Improved aggregation can enhance infiltration and water retention and reduce the susceptibility of soil to erosion (Ranjith and Sridevi, 2021; Kumar *et al.*, 2026).

Long-term pulse-inclusive cropping systems have been associated with improvements in microbial biomass and soil enzyme activities. Increased activities of enzymes such as urease and dehydrogenase indicate greater biological activity and nutrient-transforming capacity in soil. Pulse-cereal and pulse-rice systems have also shown greater soil organic carbon than comparable cereal-dominated systems in several long-term studies (Kumar *et al.*, 2026).

The role of pulses in soil health is also connected with soil structure. Root systems contribute to aggregation, while organic residues provide material that supports the formation and stabilisation of soil aggregates. Better aggregation can improve infiltration, aeration and water retention while reducing susceptibility to erosion and compaction. Kumar *et al.* (2023) similarly highlighted the positive contribution of pulse-based systems to soil properties, nutrient cycling and resource-use efficiency.

Thus, the effect of pulses on soil should not be viewed only through the amount of nitrogen fixed. Their contribution is broader, involving biological activity, carbon inputs, nutrient cycling and physical improvement of the soil environment.

Pulses in Crop Rotation and Intercropping

The benefits of pulses become particularly evident when they are integrated into diversified cropping systems (Table 2). Continuous cereal cultivation can result in repeated extraction of similar nutrients and can favour particular pest, disease and weed complexes. Introducing a pulse provides a biological and agronomic break within the cropping sequence.

In India, pulses can be incorporated into rice-, wheat-, maize-, sorghum- and cotton-based systems. Short-duration mungbean and blackgram are particularly useful for occupying seasonal niches such as rice-wheat fallows. Their inclusion can increase cropping intensity and improve the productive use of residual soil moisture without requiring additional land (Kumar *et al.*, 2026).

Intercropping provides another opportunity. Pulse crops may be grown together with cereals or commercial crops so that different crops use available light, water and nutrients at different rates and depths. In rainfed environments, pulse-based intercropping can help stabilise overall system productivity under variable rainfall. The diversification itself also reduces dependence on a single crop and therefore can lower production risk (Kumar *et al.*, 2026).

Table 2: Major contributions of pulses to sustainable cropping systems

Agricultural function	Contribution of pulses
Biological nitrogen fixation	Adds biologically fixed nitrogen and reduces dependence on external N inputs.
Nutrient cycling	Pulse roots and residues contribute N and organic matter.
Soil biological activity	Supports microbial biomass and enzyme activity.
Soil structure	Root growth and organic inputs favour aggregation.
Crop diversification	Breaks continuous cereal cultivation.
Water management	Several pulse crops can be effectively integrated into rainfed and moisture-limited cropping systems.
Climate resilience	Diversified systems are better able to cope with climatic variability.
Farm sustainability	Can reduce input dependence and diversify production and income.

[Source: Ranjith and Sridevi (2021); Kumar *et al*. (2023); Kumar *et al*. (2026)]

Pulses can therefore function as both rotational and companion crops. Their integration with cereals can diversify crop growth periods, rooting patterns and nutrient acquisition, while interrupting continuous cereal cultivation. Such diversification can improve resource-use efficiency and contribute to greater stability of the overall cropping system (McDermott and Wyatt, 2017; Kumar *et al.*, 2026).

Pulses and Resource Conservation

Resource conservation is becoming increasingly important as agriculture faces greater climatic uncertainty and pressure on land and water resources. Pulses are frequently cultivated in rainfed and resource-constrained environments, where soil moisture and fertility may vary considerably from season to season. Their adaptability to such conditions and their potential to contribute to nutrient cycling make them valuable components of diversified rainfed agroecosystems (Kumar *et al.*, 2023).

The water-use advantage of pulses is not universal and depends on species, soil, climate and management. Nevertheless, several pulse crops can fit effectively into cropping sequences where residual soil moisture is available. Short-duration pulses can make use of otherwise unproductive periods, while deep-rooted legumes can explore soil layers beyond the immediate rooting zone of shallow-rooted crops.

The inclusion of pulses can therefore improve resource-use efficiency at the cropping-system level, rather than simply through the performance of an individual crop. This distinction is important. Sustainable agriculture is ultimately concerned with how efficiently the whole system converts land, water, nutrients and solar energy into food and other useful outputs.

Pulses, Carbon and Climate Resilience

Pulse-based systems also have relevance to climate-change mitigation and adaptation. Biological nitrogen fixation can reduce dependence on synthetic nitrogen fertilisers, while pulse residues and root-derived inputs contribute organic carbon to the soil. Pulse-inclusive cropping systems may therefore support nutrient cycling, soil-carbon management and resource conservation (Ranjith and Sridevi, 2021; Kumar *et al.*, 2026).

According to Kumar *et al.* (2026), pulse-inclusive systems have demonstrated potential for increasing soil organic carbon and reducing the environmental burden associated with fertiliser use. The authors also highlighted the role of pulses in improving resilience to climatic variability through diversification, improved nutrient cycling and better resource-use efficiency.

These benefits should not be interpreted as meaning that pulses alone can solve the climate challenge. Rather, they form one important component of a broader package that includes conservation agriculture, balanced nutrient management, improved varieties, efficient water management and appropriate crop diversification (Figure 2).

Pulses and Biodiversity in Agricultural Systems

Diversification with pulses can also influence biodiversity within agricultural systems. Changing crop species across seasons modifies the habitat and resources available to soil organisms, insects and other components of the agroecosystem. Pulse roots and residues provide different organic substrates to microorganisms and can influence the biological functioning of the soil (Kumar *et al.*, 2026).

Pulse crops can also function as break crops. By interrupting continuous cereal cultivation, they may help disrupt crop-specific pest and disease cycles. Pulse-based diversification can therefore complement integrated pest, disease and weed management and contribute to a more biologically diverse and resilient agroecosystem (Ranjith and Sridevi, 2021; Kumar *et al.*, 2026).

The resulting system is therefore more biologically diverse than a simple cereal monoculture. Greater diversity can improve the capacity of agroecosystems to withstand environmental disturbances, although the magnitude of the benefit depends on the crops, rotation, management practices and local ecological conditions.

The Farm-to-Plate Connection

Perhaps the most important feature of pulses is that their agricultural and nutritional functions are closely connected. The same crop that contributes to nutrient cycling and soil fertility also provides protein-rich food for people. This connection is particularly meaningful in smallholder and rainfed farming systems, where agricultural production is closely linked with household food and livelihood security (Kumar *et al.*, 2023).

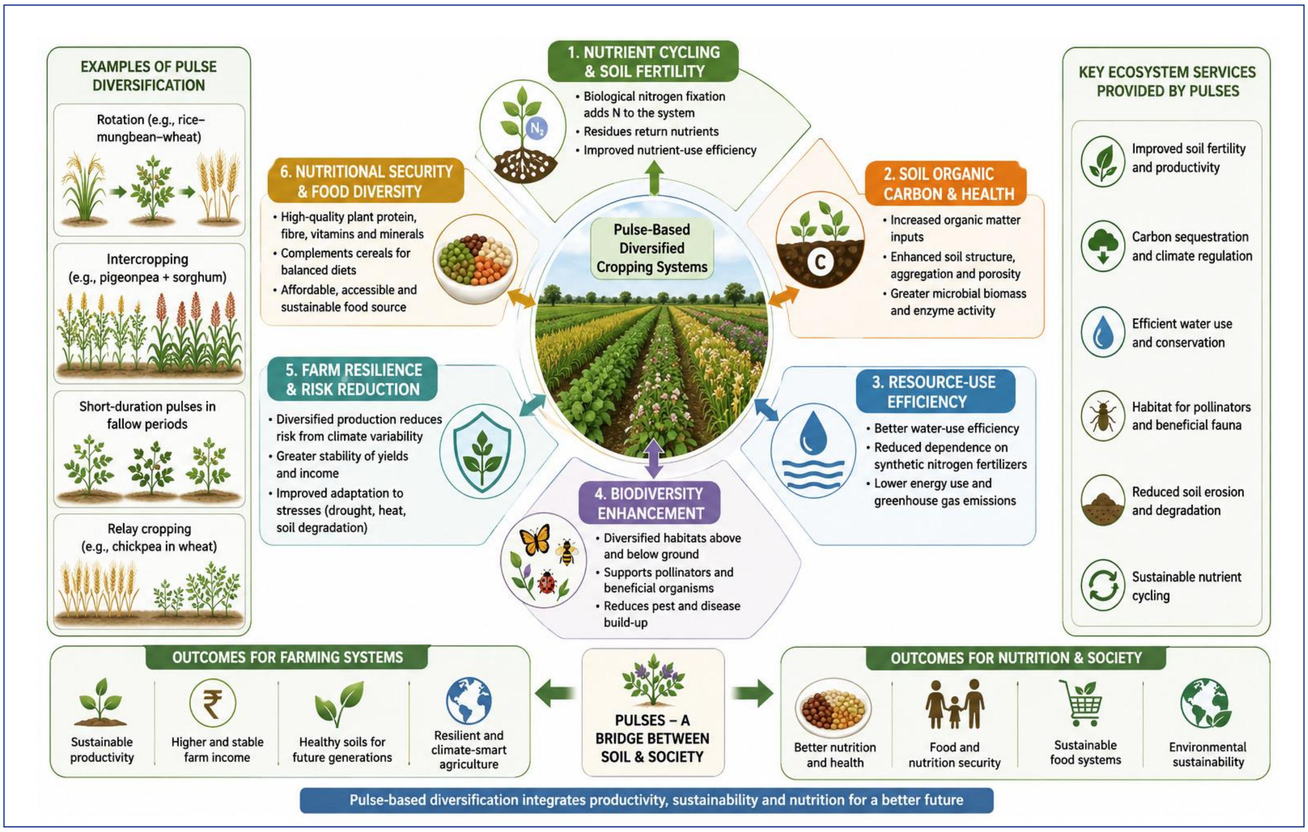

Figure 2: Pulse-based diversification: Multiple benefits for sustainable agriculture

However, the contribution of pulses to nutrition cannot be achieved through production alone. Efficient supply chains, storage, processing, markets, consumer awareness and nutrition-sensitive policies are also required to make pulse-based foods accessible and affordable. McDermott and Wyatt (2017) emphasised the need for coordinated action across agriculture, food processing, markets, health and policy sectors to increase the contribution of pulses to healthier and more sustainable food systems.

Yet, despite these advantages, pulse production continues to face several constraints. Productivity remains lower and more variable than that of major cereals in many environments. Pests and diseases, limited mechanisation, inadequate access to quality seed, climatic stresses and insufficient policy and market support continue to restrict the expansion of pulse cultivation (Kumar *et al.*, 2026).

The solution, therefore, is not simply to increase the area under pulses. Greater attention is needed towards improved varieties, short-duration and stress-tolerant genotypes, better agronomic management, efficient water use, mechanisation and improved post-harvest handling. At the same time, consumer awareness and dietary diversification need to increase so that greater production is matched by greater utilisation.

A Sustainable Future with Pulses

Pulses should increasingly be considered as multifunctional crops rather than only grain-producing crops. Their value includes food and nutrition, biological nitrogen fixation, soil fertility, carbon management, resource conservation, biodiversity and livelihood diversification. Realising these multiple benefits, however, requires coordinated action across production, research, value chains, markets, food processing and nutrition policy (McDermott and Wyatt, 2017; Kumar *et al.*, 2026).

Kumar *et al.* (2023) emphasised that pulse-based cropping systems have particular relevance for restoring soil health and conserving resources in rainfed agroecosystems. Kumar *et al.* (2026) further highlighted their potential to enhance nutrient cycling, soil health, water-use efficiency, biodiversity and climate resilience. Together, these findings support a broader approach in which pulse cultivation becomes an integral component of sustainable intensification rather than a secondary crop grown only when conditions permit.

The future of pulse production will depend on bringing these multiple benefits into practical farming decisions. A suitable pulse in a suitable rotation, supported by appropriate agronomic management, can improve both the productivity of the present crop and the condition of the soil for crops that follow.

Conclusion

Pulses provide a remarkable link between human nutrition and soil health. Their grains supply protein, dietary fibre, minerals and vitamins, while their roots and residues contribute to biological nitrogen fixation, organic matter and nutrient cycling. Their inclusion in crop rotations, intercropping and conservation-oriented systems can improve soil biological activity, support soil structure, conserve resources and strengthen the resilience of farming systems.

Their importance should therefore be assessed beyond yield alone. A pulse crop contributes food to the household, nitrogen to the cropping system, organic matter to the soil and diversity to the farm. This combination makes pulses particularly relevant to the present challenge of producing nutritious food while protecting the natural resource base.

Greater investment in pulse research, improved varieties, agronomic management, market support and consumer awareness is needed to realise this potential. If these efforts are pursued together, pulses can move from being an often underutilised crop group to becoming a central component of resource-efficient, climate-resilient and nutritionally secure agriculture.

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