*Indian Farming* 76 (07): 51-53; July 2026

# Sustainability spectrum of forage legumes: From soil builders to food, feed and fuel

**Shruti Setia, Sudha Yadav and Hardev Ram***

*ICAR-National Dairy Research Institute, Karnal, Haryana 132 001*

*The modern input intensive agriculture has increased sustainability challenges. Degraded soils, limited land and water resources, heavy chemical reliance and climate change has necessitated urgent measures to feed the growing population. Amid all these challenges, forage-legumes stand out as most beneficial and multi-functional crop providing fuel for industries, feed supplement for animals, health to the soil and many services to the ecosystem, giving ecological, economical and nutritional solution at once. This versatility has resulted from the deep-rooted symbiosis, million years of evolution and adaptive traits that makes them the future ready crop. It fulfills the 3P's of sustainability - People, Planet and Profit. This article discusses the legume sustainability and versatility spectrum.*

**Keywords:** Biofuel, Cover crop, Ecosystem services, Soil health

LEGUMES are the second most important crop family and the oldest staple food across the world having diverse biotic and abiotic adaptations. They are the most diverse crops, some are used for forages and some are consumed as pulses by humans. They account from herbaceous to woody; tropical to subtropical and temperate; from pasture to agroforestry; annuals to bushy perennials. Moreover, the nature's blessing to legume is that they fix their own nitrogen by showing symbiosis with some bacteria, nourishing itself and other surrounding plants and microbiota. It enhances nutrient cycling by incorporation of N-rich legume forage to the soil. This nitrogen in plants get converts to crude protein which enhances the work efficiency, health and milk production in animals. Besides crude protein, it also has higher starch, fibre, and antioxidants. Also, they show abiotic adaptations by growing in harsh climates like drought and contribute some production in adverse climatic conditions. As green manure, it improves the soil health while as a cover crop, it manages erosion, gives shade, and also provide pharmaceutical products and many others. But to utilise full versatility of legumes, we have to explore its full genetic potential which is underexplored till date.

## Legumes as soil builders

One of the important contribution of legumes lies beneath the soil. Legumes belongs to family Leguminosae, known for their nitrogen fixing ability. Their roots forms nodules which hosts the rhizobia bacteria, known for fixing atmospheric nitrogen in anaerobic conditions. The nitrogen thus produces is in plant available ammonium form, which reduces the need of synthetic fertilisers resulting in less nitrate leaching, better soil health, less green-house gas emission and low economic cost. Rhizobia not only fixes nitrogen but also solubilises phosphorus and promote root growth. Crops like cowpea, alfa-alfa, pigeon pea, mung bean, etc. enrich the soil with residual nitrogen which benefits plants in subsequent rotation. Among these, alfa-alfa (*Medicago sativa*) has highest N-fixing ability. Their diverse root system architects the soil into stable aggregation, improves soil aeration, increase infiltration, prevents erosion and enhance soil organic matter content. They can be planted on degraded lands for soil stabilisation and rehabilitation like *Gliricidia, Leucaena,* and *Mimosa* spp. Legumes enhance microbial activity and diversity in the soil by interacting with *Rhizobium*, mycorrhizae

**Table 1.** Nitrogen fixation by different forage legumes

| Crop | Reported BNF (kg N/ha/yr) |
|---|---|
| Cowpea (*Vigna unguiculata*) | 20–240 (seasonal) |
| Clusterbean (*Cyamopsis tetragonoloba*) | 30–196 (seasonal) |
| Berseem clover (*Trifolium alexandrinum*) | 115–400 (seasonal) |
| Lucerne / Alfalfa (*Medicago sativa*) | 50–466 |
| Lablab / Hyacinth bean (*Lablab purpureus*) | 100–200 |

BNF: Biological Nitrogen Fixation.

and plant growth promoting rhizobacteria. Thus, they improve nutrient solubilisation, suppress soil borne plant pathogens and build long term soil fertility.

### Legume as food

Legume serve as nutrient dense staple diet all over the world, nourishing civilisations for many years. From Middle East lentils to chickpeas in India, soybean in East Asia, and cowpeas of Africa, they are deeply woven in our food culture. Known for their high nutritive value, the dried seeds of legumes-pulses, are rich in nutritional aspects. They have about 18–40% protein content, rich in amino acid, dietary fibre and minerals like iron, zinc, folate and B-vitamins. It is also rich in antioxidants and anti-inflammatory compounds, which reduces the chances of cardiovascular diseases and prevent from lung, kidney, pancreatic and breast cancer. They also serve as green leafy vegetable. It offers sustainable and affordable protein source without leaving carbon footprint on environment as compared to animal based protein. Leaves of forage legume serve as a vegetable source for humans rich in nutritive value.

### Legume as feed

Legume forage offers superior nutritive value as compared to grass forage. It has higher crude protein, better digestibility and improved dry matter intake by animals. Species like alfa-alfa, *Desmodium*, *Arachis pintoi*, etc. improves livestock productivity. Integrating legumes with grasses enhances the system sustainability as legume provides nitrogen to grasses and improve overall biomass production and offer high quality forage to animals. The leguminous trees serve as fodder banks in dry season, when no other fodder crop could be taken, these trees planted as silvipastoral system serve as protein reserves.

### Legume as fuel and industrial sources

In recent times, bioenergy is gaining importance because of their little to no negative impact on climate as compared to fossil fuel burning. Major sources of biofuel is wood, leguminous trees and shrubs, serving as fast growing biofuel sources like bioethanol and biodiesel. Oil rich legumes like soybean and *Pongamia pinnata* are important crops for biodiesel production.

They also produce adhesive, binders and excipients which have great importance in pharmaceuticals, production of biodegradable plastics and livestock feed additives, thus, commercialising their production on a large scale. Isoflavones and polyphenols are also used in hormonal balancing drugs and functional foods.

### Legumes as ecological and climate allies

Legumes also provide ecosystem services that are crucial for climate change mitigation and adaptation in changing climatic scenario. It enhances the soil organic carbon through root biomass and improves microbial activity and aggregation. It can be grown as an ideal cover crop to bind the soil and stop erosion in fallow season. Beside this, it also adds organic matter to soil when incorporated.

Legume cover cropping in a maize and soybean system increased soil carbon storage by 6.6 g/m$^2$ over a 13-year period when compared to a conventional system without cover crops, which showed no net change in carbon storage. It reduces the requirement for synthetic sources of inorganic nitrogen fertiliser. They serve as a forage for pollinators, sequester carbon to the soil. It contains condensed tannins, which might reduce GHG emission by reducing methane emission from rumen.

### Constraints

Forage legumes are important for sustainable agriculture, but some farm policy and incentive barriers challenges its wide adoption. Particularly in India, during and after Green revolution, emphasis was given on input intensive, high yielding rice–wheat cropping system, thus lacking behind in legume production. Also, the input intensive system is more economical in short run, while forage legume system tends to

**Table 2.** Nutritional value of different fodder crops

| Crop | DM (% as fed) | Crude protein (% DM) | NDF (% DM) | ADF (% DM) | Ash (% DM) | Gross energy (MJ/kg DM) |
|---|---|---|---|---|---|---|
| | | | ***Kharif* crops** | | | |
| Maize | 22–25 | 7–9 | 60–65 | 30–35 | 6–8 | 17.5–18.0 |
| Sorghum | 25–30 | 8–10 | 55–60 | 32–36 | 8–10 | 18.0–18.5 |
| Cowpea | 18–22 | 18–22 | 40–45 | 28–32 | 12–14 | 17.0–17.5 |
| Clusterbean / Guar | 20–25 | 16–20 | 45–50 | 30–35 | 10–12 | 17.0–17.8 |
| | | | ***Rabi* crops** | | | |
| Berseem | 12–15 | 18–21 | 38–42 | 25–30 | 14–16 | 16.8–17.2 |
| Lucerne | 18–22 | 18–22 | 40–45 | 28–32 | 10–12 | 17.0–17.5 |
| Oat | 18–22 | 10–12 | 55–60 | 30–35 | 8–10 | 17.5–28.0 |
| | | | **Grasses** | | | |
| Napier / elephant grass | 20–25 | 8–12 | 65–72 | 38–42 | 9–11 | 17.5–18.0 |
| Guinea grass | 22–28 | 9–12 | 60–68 | 35–40 | 8–10 | 17.8–18.2 |

DM: Dry matter; NDF: Neutral detergent fibre; ADF: Acid detergent fibre.

provide benefits in long term, making farmers reluctant to grow it. For more sustainable system in agriculture, these policies need to be tailored to provide equitable attention to these low input highly sustainable systems to mitigate and adapt climate change events.


## SUMMARY

Legumes serve as a cornerstone of sustainable agriculture due to their remarkable diversity, versatility and ecological benefits. Being soil builders, they enhance nitrogen availability, improves oil structure, enhance microbial activity and reduce erosion, thus, reducing dependence on synthetic chemical fertilisers. As food and feed, they provide highly nutritious, proteinaceous, high-quality, and affordable source, therefore boosting food security and livestock productivity. Their extended role in bioenergy production, industrial applications and climate resilience through carbon sequestration, make them more important for current scenario. Despite these, their potential remain underutilised due to lack of policies, and limited genetic exploitation. Long-term soil health, climate adaption, and resilient agri-food systems depend on the promotion of legumes within sustainable grassland and farming systems, backed by suitable policies and incentives.



*Corresponding author email: devagron@gmail.com