Indian Farming 76 (07): 29-31; July 2026

Lignocellulosic natural fibres: India's green path to SDGs

Arvind Kumar Singh* and Gouranga Kar

ICAR-Central Research Institute for Jute and Allied Fibres, Barrackpore, Kolkata, West Bengal 700 121

Lignocellulosic natural fibres such as jute, kenaf, ramie, sunnhemp and sisal constitute a strategic renewable resource base for India's transition towards a low-carbon, and circular bioeconomy. Research-led innovations from ICAR-CRIJAF have enabled biodegradable alternatives to plastics, enhanced carbon sequestration of 3.8 t C/ha/year, and unlocked second-generation bioethanol potential of up to 12,000 L/ha, achieving around 80% reduction in greenhouse gas emissions compared with fossil petrol. These fibres integrate agricultural sustainability, industrial resilience, farmer welfare and national commitments to the Sustainable development goals.

Keywords: Bioethanol, Carbon sequestration, Circular bioeconomy, Plastic alternatives, Sustainable development goals

THE growing global concern over climate change, plastic pollution, fossil fuel dependence and environmental degradation has accelerated the search for renewable, biodegradable and climate-smart materials. In this context, lignocellulosic natural fibres particularly bast fibres (fibre found in the inner bark of the stems) have re-emerged as critical resources for sustainable agriculture and green industrial development. India, with its long tradition of bast fibre cultivation, stands uniquely positioned to harness these fibres as a foundation for a bio-based circular economy. Among lignocellulosic fibres, jute (*Corchorus* spp.), kenaf (*Hibiscus cannabinus*), ramie (*Boehmeria nivea*), sunnhemp (*Crotalaria juncea*) and sisal (*Agave sisalana*) represent high-potential crops owing to their rapid biomass accumulation, low input requirements, wide agro-climatic adaptability and multifunctional end uses. These fibres are not only raw materials for textiles and packaging but also serve as feedstock for biocomposites, geotextiles, pulp and paper, bioenergy and second-generation biofuels.

India cultivates jute over approximately 0.68 million hectares, producing an average of 25 t/ha of aboveground biomass, with additional by-products such as sticks and leaves. When strategically managed, these fibre crops generate ecosystem services such as carbon sequestration, soil health improvement, reduced greenhouse gas emissions and substitution of synthetic, petroleum-based materials. Consequently, lignocellulosic fibres directly support Sustainable Development Goal (SDG) 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land), while also contributing to SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth) and SDG 9 (Industry, Innovation and Infrastructure).

Lignocellulosic fibre composition and crop improvement

***Chemical composition of bast fibres*:** Lignocellulosic fibres are primarily composed of cellulose, hemicellulose and lignin, arranged in a hierarchical structure that determines their mechanical strength, biodegradability and processing behaviour. Cellulose, hemicellulose and lignin values vary across varieties and growing environments. Cellulose provides tensile strength and flexibility, hemicellulose contributes to fibre cohesion, and lignin imparts rigidity and resistance to microbial degradation. From an industrial perspective, high

Ramie cultivation

cellulose and low lignin content are desirable for textile applications, bioethanol production and biocomposites, as they reduce processing costs and chemical inputs. Kenaf exhibits slightly lower cellulose content (~54%) with relatively higher lignin, while ramie is characterised by exceptionally high cellulose concentration in the secondary cell wall. This makes ramie the strongest natural bast fibre known today. Because of this strength and quality, ramie is considered a premium fibre for high-performance textiles and technical applications.

***Genetic resources and crop improvement*:** India possesses one of the world's richest repositories of bast fibre genetic resources. ICAR-Central Research Institute for Jute and Allied Fibres (CRIJAF), Barrackpore conserves over 5,800 accessions of jute, mesta and allied fibres, serving as the backbone for crop improvement programmes. Through systematic breeding and selection, nearly 100 improved varieties of jute and allied fibres have been released since independence. These varieties have collectively increased jute productivity by nearly threefold since 1947, primarily through:

- Resistance to premature flowering.
- Improved fibre strength and fineness.
- Enhanced adaptability to biotic and abiotic stresses.
- Compatibility with mechanisation and modern agronomic practices.

Notably, low-lignin mutants containing as little as 8% lignin have been developed, enabling production of fine fibres (~1.5 tex) suitable for apparel-grade textiles and advanced composites.

Biomass productivity

Jute varieties with ~60–65% cellulose, can produce 60–80 t/ha of total biomass under optimal management, making them highly attractive for bioenergy and biorefinery systems. Lignocellulosic fibre crops are characterised by rapid biomass accumulation.

By-product utility and circular agriculture

One of the most significant contributions of lignocellulosic fibre crops lies in their near-zero waste potential. In jute cultivation, fibre constitutes only about 10–12% of total biomass, while the remaining 88–90% is available as by-products.

- Jute sticks (approx. 40% of biomass) are used as fuel, particle boards, charcoal, pulp and as feedstock for bioenergy.
- Leaves, rich in micronutrients (notably 173 mg/kg iron), contribute to household nutrition and livestock feed.
- Retting residues and leaf litter enhance soil organic carbon and nutrient cycling.

Mesta cultivation

Collectively, by-products can generate an additional income of ₹8,000–10,000/ha, significantly improving farmer profitability and resilience.

Sustainability innovations in fibre production and processing

***Microbial retting technologies*:** Traditional retting of jute in stagnant water bodies is labour-intensive, time-consuming and environmentally problematic. The development of CRIJAF SONA microbial retting technology represents a major breakthrough. This technology:

- Reduces retting duration to 10–15 days.
- Enhances fibre strength to ~27.8 g/tex.
- Improves fibre colour and uniformity.
- Reduces water pollution and methane emissions.

By cutting water use and effluent load, microbial retting aligns fibre processing with environmental regulations and climate commitments.

***Climate-smart cropping systems*:** Integration of jute into jute–rice cropping systems has demonstrated substantial ecosystem benefits. These systems sequester approximately 3.8 t C/ha/year, translating to 2.85 million tonnes of CO_2 absorption from about 0.75 million ha. At prevailing voluntary carbon market prices, this sequestration potential corresponds to an estimated carbon credit value of about USD 150 million annually.

Plastic replacement and green industrial products

Synthetic plastics pose severe environmental hazards due to persistence, toxicity and fossil carbon emissions. Lignocellulosic fibres provide a viable alternative for single-use plastics (SUPs) and packaging

Table 1. Composition of bast fibres and their key characteristics

Fibre crop	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Biomass (t/ha)	Key trait
Jute	58–65	18–21	12–14	25	High bioethanol yield (492 L/t)
Kenaf	54	18	20	22	Plastic bag alternative
Ramie	High (secondary wall)	Variable	Moderate	Variable	Strongest bast fibre
Sunnhemp	Variable	Variable	Variable	High GM	N-fixing green manure
Sisal	High	Low	High	Perennial	Drought-tolerant

Model of lignocellulosic bast fibres

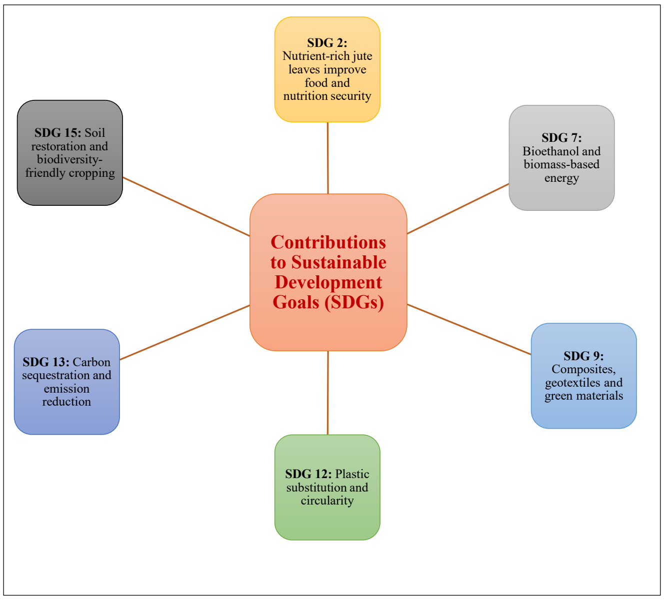
materials. Life cycle assessment was done and revealed that:

- Jute and kenaf bags exhibit 490 times lower global warming potential (0.72 kg CO_2 eq/kg) compared with LDPE (Low-density polyethylene) bags (39.4 kg CO_2 eq/kg).
- Net emissions from jute products are negative (−1.26 kg CO_2 eq/kg) when carbon sequestration is accounted for.
- Reusability (up to 30 cycles) and biodegradability reduce ecotoxicity and eutrophication impacts by 90%.

With India producing approximately 9.87 million bales of jute annually, the scaling of fibre-based alternatives can significantly support national bans on SUPs (Single use plastics) while generating rural employment across the value chain.

Bioethanol and bioenergy potential

Second-generation bioethanol production: Lignocellulosic biomass from jute and kenaf is an excellent feedstock for second-generation (2G) bioethanol. Using alkali pretreatment and enzymatic fermentation, jute biomass yields 492 L ethanol per tonne while kenaf yields 451 L ethanol per tonne. Net



greenhouse gas emissions from these pathways are only 3.45–5.88 g CO_2 eq per MJ, representing a 78–81% reduction compared to petrol.

Implications for farmers' welfare and national policy

The multifunctional role of lignocellulosic fibre crops positions them as risk-buffering enterprises under climate variability. Low input requirements, diversified income streams, and expanding industrial demand enhance farmer welfare while supporting national priorities such as *Atmanirbhar Bharat*, bioenergy missions, plastic waste management rules and climate commitments. Integrated farming system models involving fibre crops have demonstrated up to 92% increase in farm income, supporting livelihoods of nearly 5 million households.

SUMMARY

Lignocellulosic natural fibres particularly jute, kenaf, ramie, sunnhemp and sisal represent a scientifically validated, economically viable and environmentally sound pathway for India's agricultural and industrial transformation. Rich in cellulose (up to 65%), these fibres deliver high strength, biodegradability and versatility across textiles, packaging, composites and bioenergy. With jute cultivated on 0.68 million hectares producing 25 t/ha biomass, the sector delivers substantial ecosystem services, including 3.8 t C ha/year sequestration and significant greenhouse gas mitigation. Innovations such as microbial retting, low-lignin genotypes, and high-cellulose varieties have unlocked opportunities for plastic substitution, second-generation bioethanol production (up to 12,300 L/ha) and circular bioeconomy development. Collectively, these advances enhance farmer's income, strengthen climate resilience, promote resource efficiency and accelerate India's progress towards multiple SDGs.

*Corresponding author email: singhak30@gmail.com