



## Circular Economy of Millets

**Divya Devkar\***

Department of Statistics and Computer Application, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

**\*Corresponding Author:** Divya Devkar, Department of Statistics and Computer Application, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India.

**DOI:** 10.31080/ASAG.2024.08.1377

**Received:** April 01, 2024

**Published:** May 22, 2024

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### Abstract

Millets, a resilient and nutritious grain, are regaining prominence as a sustainable and circular crop. Once overshadowed, millets now contribute to closed-loop, eco-friendly farming. India leads in millet production, embodying circular economy principles by harmonizing economic activities with environmental well-being. Through diverse farming practices rejuvenating soil, repurposing grains/straws, and aligning with UN SDGs, the circular economy of millets offers advantages like responsible consumption/production and climate action. This article explores millets' transformative impact, innovative methods, farmer benefits, waste utilization, and increasing consumer awareness, positioning millets as a pathway to sustainable agriculture nurturing ecosystems, and reshaping our food-land connection.

**Keywords:** Millets; Circular Economy; Sustainable Agriculture; Climate Change; Eco-Friendly; Nutrition

### Introduction

Amidst the intricate fabric of agriculture, where the strands of tradition and innovation entwine, a humble yet potent grain is gradually stepping back into the limelight - millets. Millets are a crop that can be cultivated throughout the year and is grown worldwide (Priya *et al.*, 2023) [12] however, in the post-Green Revolution era, their cultivation has notably decreased as there has been a greater emphasis on rice, wheat, and maize. The world's total production of millets is about 30,859,664 tonnes and India is one of the largest producers of millets globally with a total production of 11,849,190 tonnes (FAOSTAT, 2021) [10]. Envision a realm where agriculture transcends mere yields and evolves into a practice that nurtures ecosystems. In this scenario, every facet of the cultivation process actively contributes to a closed loop of sustainability. This encapsulates the core philosophy of the circular economy, with millets seamlessly embodying its principles. The narrative surrounding millets extends beyond agriculture; it involves reshaping our connection with land, with food, and with the fundamental essence of sustaining life.

This article delves into millets' transformative impact across innovation and tradition realms. Their resilience and nutrition

are significantly transforming agricultural methodology through soil-rejuvenating diverse farming practices and grain/straw repurposing methods, steering towards sustainable ecosystems. With substantial influence on sustaining agricultural practices, millet's circular economy plays a crucial role in overcoming global challenges, potentially achieving UN SDGs 12 (Responsible Consumption and Production) and 13 (Climate Action). The circular economy is an economic growth strategy aligning environmental and economic sustainability. By conceptualizing the harmonious integration of economic activities and environmental well-being, the circular economy of millets diminishes adverse environmental effects while creating business prospects, dating back to industrialization onset.

As we explore the circular economy surrounding millets, we will reveal numerous advantages for farmers, innovative methods of turning waste into valuable resources, and the increasing awareness among consumers that is reshaping the market landscape. Millets are more than just crops; farm gates, from the fields to our dining tables.

Types of Millets and their Characteristics

Millets	Characteristics
Sorghum	Withstands moisture stress and high temperatures better than any other crops.
Guinea millet	Potential as a grain crop
Finger millet	Wider adaptability, a rich source of calcium
Pearl millet	Grow in arid and semi-arid regions, the richest source of folic acid
Foxtail millet	Short duration, tolerant to low soil fertility and drought
Kodo millet	Long duration, grown well in shallow and deep soil, rich in folic acid
Proso millet	Short duration, tolerant to heat and drought
Barnyard millet	Fastest-growing, voluminous fodder
Browntop millet	Rapidly maturing, best suited for catch crop
Job's tears	Grown in higher areas, used in folk medicine
Little millet	Short duration, withstand both drought and waterlogging

Table a

Cultivation of millets

Millets are a diverse group of cereal grains belonging to the Poaceae family, commonly known as the Gramineae family. This is one of the largest and most economically important plant families, encompassing over 10,000 species with various ecological and agricultural roles. Several cultivated species belonging to the Poaceae family, including pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), and foxtail millet (*Setaria italica*), are collectively referred to as “millets.” Millet cultivation spans 93 countries globally, with only seven exceeding 1 million hectares in dedicated acreage. Developing nations are responsible for over 97% of global millet production and consumption. A study revealed a substantial decline of 25.71% in the area allocated to millet cultivation across continents from 1961 to 2018. Conversely, global millet productivity has witnessed a significant increase of 36%, rising from 575 kg/ha in 1961 to 900 kg/ha in 2018. A global examination of trade data indicates that millet imports and exports reached their peak values between 2011 and 2017, with imports reaching 155.26 million US\$ and exports reaching 127.60 million US\$ (FAOSTAT, 2018) [10].

Certain millet species exhibit significant tolerance to diverse environmental stressors like drought, excessive precipitation, and insect infestation. This resilience, coupled with their nutritional profile, suggests their potential as climate-resilient food security



Figure a

crops. Studies demonstrate waterlogging tolerance in certain barnyard millet cultivars, indicating their suitability for flood-prone or waterlogged agricultural areas. As C4 photosynthetic plants, some millets exhibit higher water-use efficiency and potentially enhanced carbon fixation compared to C3 crops like rice and wheat under specific conditions. Their C4 pathway indirectly contributes to increased oxygen release via elevated carbon fixation during photosynthesis. While not inherently “releasing more oxygen” than other crops, millets’ C4 metabolism can lead to improved carbon assimilation efficiency, potentially exerting a more significant impact on the carbon cycle under conducive environmental conditions.

Nutritional importance

Malnutrition, including micronutrient deficiencies (“hidden hunger”), poses a significant global challenge as per the Food and Agriculture Organization (FAO) data [11]. Millets exhibit a comprehensive nutritional profile rich in essential minerals, vitamins, proteins with balanced amino acids like sulfur-containing ones, and health-promoting phytochemicals like lignans, phytosterols, polyphenols, and antioxidants. Their prebiotic potential enhances gut probiotic efficacy. Compared to major cereals, millets boast a superior nutrient composition and bioactive flavonoids with pharmacological applications. Notably, millets aid in diabetes management, haemoglobin increase, constipation reduction, anti-cancer

properties, stomach ulcer prevention by alkalinization, mitigating migraines and respiratory issues like asthma due to high magnesium content, facilitating weight loss via high fiber content and high digestibility, with a low allergenic response. These attributes underscore millets' significance as valuable nutrient-dense crops addressing malnutrition concerns.

### Value Added Products

Post-harvest processing transforms raw millet kernels into palatable, consumable forms, potentially improving quality. Primary processing yields diverse edible formats:

- Polished rice-like grains
- Flour from whole or dehulled grains.
- Nutritionally enhanced sprouts
- Pre-cooked, seasoned ready-to-eat products.
- Flattened/rolled flakes for quick cooking.
- Puffed, popped grains with crispy texture.
- Cooked, thick, and sweetened porridge.
- Fermented products with enhanced shelf-life, flavor, and digestibility.

For diabetics, options include khichadi, laddu, batti, buns, bread, muffins, pizza base, noodles, and dosa.

### Waste management

Millet waste, like husks and straw, holds immense potential for resource recovery through innovative methods like upcycling into valuable products like paper, bio-composite materials, or even animal feed, promoting a circular economy for sustainable millet production. One of the research projects shows that adobe bricks reinforced with indigenous Cameroonian building practices of incorporating 2% red millet fibers demonstrate improved thermal, mechanical, and durability metrics compared to conventional materials. Another study exploring paper production from millet husk revealed that paper made entirely from the millet husk had the highest grammage per square meter (GSM), indicating it was the densest among the tested options, indicating the potential of agricultural residue repurposing for sustainable construction applications. Implementing effective recycling practices for millet waste is crucial to ensure the sustainability of the entire millet value chain.

### Market Demand

Effective market strategies are necessary to stimulate demand at different levels:

- **Farm gate level:** Creating incentives for farmers to add value to their produce.

- **Start-up level:** Encouraging entrepreneurship in the millet sector.
- By implementing these comprehensive measures, a sustainable and effective value chain model for millets can be established, leading to increased production and consumption.

### Opportunities and challenges

Millets in India are undergoing an image transformation from a staple for the underprivileged to a trendy, health-conscious choice, evident in the rise of millet-based products like pizzas, noodles, and baking mixes, particularly in metropolitan areas. This aligns with shifting consumer preferences towards culinary experiences, locally sourced foods, food tourism, social dining, and wellness trends, attracting entrepreneurs. However, millet entrepreneurship growth in India has been below expectations, necessitating examination of challenges. The COVID-19 pandemic disrupted global food supply chains, impacting food security and millet sector growth due to restrictive transport and labor measures. The Indian Council of Agricultural Research - Indian Institute of Millets Research (ICAR-IIMR) Hyderabad has played a pivotal role in: Millet Value Chain Development, Farm-Level Integration, Processing Technology Diversification, Recipe Development, and Dissemination. Focusing on millets and their value chain presents an opportunity to enhance demand through the development of processed food products. This can be achieved by

- Diversifying processing technologies: Implementing new methods to improve efficiency and product variety.
- Conducting nutritional evaluations: Establishing the scientific basis for the health benefits of millet-based products.
- Raising consumer awareness: Educating the public about the nutritional value and culinary versatility of millets.

Additionally, strengthening the producer base is crucial. This can be achieved through forming and supporting Farmer Producer Organizations (FPOs) and empowering farmers to collectively manage production, processing, and marketing. Food entrepreneurs catering to niche markets often face increased production costs due to sustainable/ethical practices, niche/exotic ingredients, locally sourced grains, and labor costs. Studies identify three consumer segments based on health motivations: doctor-recommended, lifestyle disease management (diabetes, hypertension, PCOS), and weight management/overall health, suggesting potential for millets as a dietary intervention and within wellness trends.

### Government policies for millets

- **Integrated Cereals Development Programmes in Coarse Cereals (ICDP-CC):** This program, falling under the umbrella of Macro Management of Agriculture, aims to provide comprehensive support to farmers engaged in millet cultivation.
- **Rainfed Area Development Programme (RADP) under RKVY:** This initiative, implemented under the Rashtriya Kishi Vikas Yojana (RKVY), targets the development of rainfed areas, which are often suitable for millet farming.
- **Initiative for Nutritional Security through Intensive Millet Promotion under RKVY:** This program seeks to enhance nutritional security by specifically promoting the cultivation of millets under the RKVY framework.
- **Production Linked Incentive Scheme for Food Processing Industry for Millet-based products (PLISMBP):** The Ministry of Food Processing Industries (**MoFPI**) implemented this program, spanning fiscal years 2022-23 to 2026-27, aims to incentivize the development of the millet-based food processing sector in India. The initiative is supported by a budgetary allocation of Rs. 800 crores.

These programs collectively demonstrate the Indian government's strategic shift and policy implementation to encourage and support millet farming practices at the national level.

### Conclusion

Millets represent a sustainable, climate-resilient agriculture pathway, embodying circular economy principles-resilience, nutrition, and versatility. Rejuvenating soils, empowering farmers, boosting food security, unlocking arid land potential, and driving innovation. Millets generate ecological, social, and economic value. Scaling initiatives, with supportive policies and consumer demand, can nourish communities and ecosystems. However, more R and D is vital to improve yield and enhance genetic diversity for truly unlocking millets' transformative potential.

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