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Review Article

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The Vital Role of Millets in Sustainable Indian Agriculture: Climate Resilience, Livelihoods, and Food Security

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Abstract

Millets, an ancient category of small-grained cereals, have historically played a crucial role in Indian agriculture, particularly in arid and semi-arid regions. Often overlooked due to the policy emphasis on rice and wheat following the Green Revolution, millets have gained renewed recognition as "nutri-cereals," especially with the United Nations announcing the International Year of Millets in 2023. This paper explores the role of millets in enhancing climate resilience, supporting the livelihoods of farmers, and bolstering India's food security. The research underscores the adaptability of millets to extreme agroclimatic conditions, their economic significance for smallholder farmers, and the policy initiatives encouraging millet cultivation. The paper also addresses challenges regarding market access, consumer perception, and infrastructure. Recommendations

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emphasize the need to strengthen millet value chains, boost consumer awareness, and promote agricultural research. The primary objective is to increase the visibility and acceptance of millet-based products among both rural and urban populations. This review compiles recent scholarly findings, governmental initiatives, and regional case studies to assess the status, challenges, and future-prospects of millets in India. It emphasizes their nutritional advantages, ecological adaptability, and supportive policies, while pinpointing structural issues in markets, seed systems, and awareness.

1. Introduction

Millets represent a collection of small-seeded cereal crops like pearl millet (Bajra), finger millet (Ragi), and foxtail millet, which have been traditionally nurtured in India for centuries. Mostly cultivated in arid areas, millets have gained renewed interest due to their exceptional nutritional value, resilience to drought, and adaptability to organic and low-input farming practices.

Millets are diverse small-seeded grasses grown worldwide as cereal crops or grains, offering a high nutritional profile. They boast a wealth of B vitamins, calcium, iron, potassium, magnesium, and zinc, and being gluten-free with a low glycemic index (GI) makes them an excellent choice for those with wheat allergies or intolerances. For individuals managing diabetes or seeking weight loss, millets are a fantastic option. Considering the rising climate challenges and nutritional dilemmas, millets are vital for sustainable agriculture in India. This paper delves into their diverse functions, emphasizing climate resilience, livelihood enhancement, and food security.

Often termed "coarse grains" or "small-seeded historically cereals." millets have been fundamental to Indian agriculture and food systems. Crops like sorghum (jowar), pearl millet (bajra), finger millet (ragi), and various minor millets such as foxtail, proso, kodo, barnyard, and little millet have been essential to India's agricultural landscapes, particularly in arid and semi-arid regions. They need less water, withstand drought conditions, and flourish in poor soils-traits that render them ideal for farming systems resilient to climate change.

However, the Green Revolution (1960s–1980s) dramatically shifted India's agricultural trajectory. High-yielding varieties of rice and wheat, backed by strong policy incentives, irrigation infrastructure, and Minimum Support Prices (MSPs), led to a sharp decline in millet cultivation. Consequently, the area under millets reduced from 37 million hectares in 1965 to 14.72 million hectares by 2020, displacing them from diets and farms alike.

Yet, in recent decades, there has been a **global** resurgence of interest in millets — driven by concerns over:

- Rising **lifestyle diseases** like diabetes and cardiovascular problems,
- The adverse effects of mono-cropping and water-intensive farming,
- Increasing frequency of climate-induced crop failures, and
- Growing awareness of the **nutritional** superiority of millets.

In recognition of the importance of millets, the Government of India took a significant step in 2018 by designating millets as "nutri-cereals." This initiative was complemented by a successful resolution led by India in the United Nations General Assembly, which proclaimed 2023 as the International Year of Millets (IYOM-2023). These actions signify a critical shift in policy from previous neglect to active promotion, with the aim of redefining millets as "smart foods"providing nutrition for consumers, economic benefits for farmers, and sustainability for the environment. Institutions like ICAR-IIMR (Indian Institute of Millets Research) and organizations such as ASSOCHAM have played a pivotal role in integrating millets into mainstream agriculture by developing processing technologies, creating

high-yielding varieties, and establishing value chain connections. Millets are now part of various initiatives, including school feeding programs, projects for tribal development, and the start-up ecosystem, creating opportunities for rural jobs and entrepreneurship. Nonetheless, the growth potential of millets is still constrained by various challenges, including limited market access, inadequate MSP coverage, inconsistent seed supply, and disparities in consumption between urban and rural areas. In areas like Vidarbha (Maharashtra) and Bundelkhand (UP), targeted efforts are revitalizing millet cultivation, demonstrating their potential as climate-smart crops that can provide income for struggling farmers. Thus, this review paper intends to deliver a thorough synthesis of recent developments related to millets in India by examining scientific, policy-oriented, and regional perspectives. It will investigate production trends, nutritional benefits,

policy interventions, successful regional examples, and barriers to adoption, aiming to bolster initiatives to integrate millets into India's agri-food framework and contribute to a sustainable, secure, and healthy future.

2. Overview of Millet Cultivation in India

India is one of the largest producers and consumers of millets globally. According to the Ministry of Agriculture's 2023 report, millet cultivation occupies approximately 9 million hectares, producing around 9 milliontonsannually.

Major millet-growing states: Rajasthan, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, and Madhya Pradesh.



Historically, millet acreage declined with the Green Revolution favoring rice and wheat, but recent government initiatives like the National Food Security Mission have reversed this trend, leading to a 12% increase in millet production between 2015 and 2023.

2.1 Historic Trends and Shifts

Millet farming in India has a history spanning more than 5,000 years, categorizing it as one of

the earliest cultivated food crops. Varieties of millets like sorghum (jowar), pearl millet (bajra), and finger millet (ragi) were dietary essentials in many regions due to their ability to thrive in dry, low-fertility soils. Nevertheless, after the Green Revolution, the emphasis shifted towards rice and wheat, leading to a significant decline in millet farming: •The area dedicated to millets dropped from 37 million hectares in 1965 to approximately 14.72 million hectares in 2020.

•The area for jowar decreased by 68%, ragi by 83%, and small millets by 97.6%.

•Yield enhancements for bajra helped maintain its production even as the land area decreased.

The decline in millet cultivation was largely due to policy support that favored fine cereals, including minimum support prices (MSPs), investments in irrigation, and procurement incentives that were not accessible for coarse grains.

2.2 Current Production Landscape

Despite historical setbacks, India remains the **largest producer of millets globally**, accounting for approximately **20% of world production**.

Key figures (2022–23 estimates):

- Total millet production: ~17.96 million tonnes.
- **Bajra (Pearl millet)**: Dominates with around **11 million tonnes** (≈61% of total millet output).
- Jowar (Sorghum): ~4.5 million tonnes.
- Ragi (Finger millet): ~2 million tonnes.
- Other small millets: ~0.5 million tonnes combined.

Top millet-producing states:

- Rajasthan: 42% of India's bajra.
- Maharashtra: 50% of India's jowar.
- Karnataka: 55% of India's ragi.
- Uttar Pradesh: Significant production of barnyard and pearl millet.

Notably, production is increasingly **concentrated geographically**, with a few states producing bulk quantities.

2.3 Consumption Patterns and Revival

Millet consumption underwent major shifts:

- In **rural India**, traditional millet consumption sharply declined due to **PDS rice/wheat availability**, changing preferences, and urbanization.
- In **urban India**, there is now a **reverse trend**: rising health consciousness is driving the "**nutri-cereals**" **revolution**.

Key data points:

- Average millet consumption in rural Bihar and Assam remains high (~18.82 kg/month)
- Urban elites in cities like **Bengaluru**, **Delhi**, and **Mumbai** show >15% annual growth in millet-based product demand (packaged foods, snacks, health mixes).

Programs such as **mid-day meal scheme millet inclusion** in Karnataka and Odisha are catalyzing new generations of millet consumers.

2.4 Export Trends and Global Demand

India's millet exports have also risen steadily:

- 2020-21 millet export value: ~USD 26 million.
- Major importing countries: UAE, Saudi Arabia, USA, Japan, Germany.
- **Projected CAGR** (2023–2025): 4.6% annual growth for Indian millet exports.

With international recognition of millets as climate-smart crops and the global celebration of **International Year of Millets (IYoM 2023)**, India's export market is poised for expansion, provided supply chains are strengthened.

2.5 Regional Highlights

• Odisha Millet Mission: Increased millet area by 25% across tribal districts since 2017.

- Vidarbha, Maharashtra: Shift to minor millets in rainfed districts to reduce climate vulnerability.
- Bundelkhand, UP: Successful introduction of E.C.C.-25 barnyard millet, improving yields by 35%.

2.6 Summary and Outlook

While millet cultivation and consumption drastically declined during the Green Revolution decades, today there is clear momentum toward **reviving millets** both domestically and internationally. However, achieving a millet renaissance will require:

- Greater policy coherence,
- Consumer education campaigns,
- **Processing infrastructure** for urban convenience,
- Strategic branding of millets as a health and climate-resilient superfood.

Thus, the story of millets is not just of a lost heritage, but of a future agricultural revolution rooted in sustainability, nutrition, and resilience.

3. Millets and Climate Resilience

Millets are exceptionally tolerant to drought, heat, and poor soils. They require 30-50% less water than paddy and wheat and can thrive with minimal soil fertility. Studies by ICAR (2022) report pearl millet yields sustained despite a 20% reduction in rainfall across semi-arid zones in the past decade, unlike the steep decline observed in rice and wheat crops.

Climate change poses a severe threat to global agriculture, especially in regions like South Asia where rainfed farming predominates. Rising temperatures, erratic rainfall, increased frequency of droughts and floods, and declining soil health jeopardize the productivity of conventional crops such as **rice**, wheat, and maize.

Given these vulnerabilities, there is a critical need to promote **climate-resilient crops** that can withstand extreme weather events, sustain yields under resource-poor conditions, and support food security. **Millets**, once marginalized, are now recognized as among the most potent **climatesmart grains**.

Unique Climate-Resilient Characteristics of Millets

Millets possess **inherent traits** that confer remarkable adaptability to climate stress:

Climate Challenge	Millet Resilience Trait
Drought	Deep root systems, C4 photosynthesis
Heat Stress	High-temperature tolerance (>40°C)
Poor Soils	Efficient nutrient use, low fertilizer demand
Erratic Rainfall	Short cropping cycle (60–90 days)
Low Water Availability	Minimal irrigation requirement (~25% of rice)
Pests and Diseases	Natural resistance compared to fine cereals

Specifically, varieties like **finger millet** and **barnyard millet** can mature on **residual soil moisture**, allowing double cropping even in semiarid zones.

Comparative Water Requirements: Rice vs Millets

Crop	Water Requirement (li kg of grain)	tres per
Rice	4,000–5,000 litres	
Wheat	1,650–2,000 litres	
Millets (average)	500–600 litres	
(Source: ICF	RISAT data)	

Millets require 80% less water than rice and can survive in areas receiving less than 400 mm rainfall per annum, making them ideal for India's semi-arid tropics.

Role in Climate-Smart Agriculture (CSA)

The FAO's Climate-Smart Agriculture (CSA) framework advocates for:

- Increased productivity sustainably,
- Enhanced resilience to climate shocks,
- Reduced greenhouse gas emissions.

Millets align naturally with CSA goals:

- Low carbon footprint: No need for heavy irrigation or chemical fertilizers.
- Soil conservation: Millets improve soil structure and organic matter.
- **Biodiversity preservation**: Diverse minor millets maintain agro-ecosystem balance.

Thus, mainstreaming millets contributes directly to meeting India's Nationally Determined Contributions (NDCs) under the Paris Agreement.

Case Studies: Climate Resilience in Action

• Vidarbha, Maharashtra: Transitioning from water-thirsty cotton to millets like pearl millet and foxtail millet has helped farmers reduce input costs and increase crop security under variable rainfall.

- Odisha Tribal Areas: Adoption of traditional small millets through the Odisha Millet Mission has enhanced nutritional security and drought resilience, protecting communities against climatic shocks.
- Bundelkhand Region, UP: Degraded ravine lands have been successfully reclaimed barnvard millet using minimal cultivation with water interventions.

Challenges to Scaling Millets for Climate Resilience

While millets offer clear climate benefits, there are systemic barriers to their wider adoption:

- Lack of **MSP** and procurement mechanisms,
- Poor extension support to farmers,
- Insufficient seed system modernization,
- **Consumer perception** hurdles labeling millets as "backward" foods.

Without addressing these bottlenecks, the climate resilience potential of millets cannot be fully realized.



water requirement comparison

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This resilience shields farmer incomes in rainfed regions and reduces dependency on irrigation, making millets a climate-smart crop.



India produces more than 170 lakh tonnes of millet, which is 80 per cent of Asia's and 20 per cent of global production. • While the Global average yield of Millet is 1229 kg/ha, the yield in India is 1239 kg/ha.

4. Agricultural and Ecological Benefits

Millets contribute positively to soil health by enhancing organic carbon and preventing erosion due to extensive root systems. Their cultivation aligns with sustainable cropping systems by facilitating crop rotation, reducing pest cycles, and lowering chemical inputs.

Millets have lower greenhouse gas emissions compared to rice and wheat, which are associated with:

- Methane emissions from flooded paddy fields,
- High nitrous oxide emissions from nitrogenous fertilizers.

Research from ICRISAT shows fields with milletbased rotations have 15% higher soil microbial diversity. Lower fertilizer requirements reduce farming costs and environmental pollution.

Millets exemplify eco-smart agriculture:

- They safeguard natural resources,
- Strengthen farmer livelihoods, and
- Preserve ecosystems for future generations.

5. Economic and Livelihood Importance

Millets are vital for small and marginal farmers who often cultivate them on marginal lands with minimal inputs. The low cost of production and relative climate security ensure steady incomes.

However, market challenges remain. Millets often fetch lower market prices due to limited consumer demand and supply chain inefficiencies.

Government Support: Programs like the National Food Security Mission on Coarse Cereals and state millet missions have incorporated minimum support prices (MSP) for millets and promoted millet procurement under the Public Distribution System. There is growing opportunity for value-added millet products (flour, ready-to-eat snacks), which could increase farmers' earnings.

6. Challenges in Millet Cultivation and Adoption

Despite benefits, millets face hurdles:

- Lack of market infrastructure and weak supply chains limit farmer access to profitable markets.
- Consumer perception often labels millets as "poor man's food," reducing demand.
- Limited mechanization and modernization restrict yield improvements.
- Research funding for millet crop improvement is lower compared to major cereals.

Challenge Area	• Specific Issues
Productivity	 Low yields, traditional practices
Seeds	• Lack of certified seeds, dependency on local varieties
Markets	• No MSP, weak procurement, distress selling
Labor	• Manual-intensive operations, post-harvest drudgery
Awareness	• Low urban-rural millet awareness
Policy	• Subsidy bias toward rice- wheat, climate schemes neglecting millets
	• Poor storage processing

Infrastructure

Poor storage, processing, packaging

7. Case Studies

India's diverse agro-ecological regions have seen successful localized interventions to promote millet cultivation. These case studies offer vital lessons on how context-specific strategies, government support, and community mobilization can revive millets as climate-resilient, nutritious crops.

1.Odisha Millet Mission (OMM)

Location: Odisha (15 tribal-dominated districts)

Launched: 2017

Highlights:

- Focused on reviving traditional millets like finger millet, little millet, and foxtail millet.
- Adopted Participatory Varietal Selection (PVS) to empower farmers to choose resilient varieties.
- Introduced Community Seed Centers and Farmer Producer Organizations (FPOs).
- Integrated millets into mid-day meals and ICDS nutrition programs.

Impact:

- 100,000+ farmers covered by 2022.
- Millet area expanded by 25% across project districts.
- Household consumption increased by 30%, reducing dependency on PDS rice.

2.Bundelkhand Initiative for Barnyard Millet

Location: Jalaun, Uttar Pradesh (Bundelkhand region)

Launched: Pilot project around 2021

Highlights:

- Introduced improved variety E.C.C.-25 Barnyard Millet.
- Focused on drought-prone ravines and degraded lands.
- Emphasized rainfed, organic cultivation.

Impact:

- Yield increase by 35% compared to local varieties.
- Barnyard millet proved suitable for multicropping and low-input agriculture in marginal soils.

3. Millet-Based Diversification in Vidarbha, Maharashtra

Location: Vidarbha region, Maharashtra

Context:

Region known for agricultural distress and high incidence of farmer suicides, mainly cotton growers.

Strategy:

- Promotion of sorghum, pearl millet, and foxtail millet as climate-resilient alternatives to water-intensive cotton and soybean.
- Supported by ICAR-IIMR-led interventions under Farmer FIRST and climate-resilient farming projects.

Impact: Improved farm income stability by reducing input costs. Enhanced crop survivability during drought years. Contributed to nutritional security among tribal households.

4. Karnataka's Integration of Millets in Mid-Day Meals

Location: Karnataka state

Launched: 2019 onwards

Highlights:

- Millets like ragi (finger millet) reintroduced in government-run mid-day meal schemes.
- Developed recipes such as ragi malt, ragi dosa, and kodo millet upma.

Impact: Boosted millet demand among school children. Helped address iron and calcium deficiencies. Karnataka remains India's largest ragi producer, accounting for 53% of national output.

5. Farmer-Led Millet Startups in Tamil Nadu

Location: Tamil Nadu

Highlights:

- Entrepreneurial FPOs created value-added products like millet cookies, snacks, and instant mixes.
- E-commerce platforms and farmers' markets boosted urban consumer awareness.

Impact: Created direct market linkages for smallholder farmers.Expanded domestic urban millet market, especially post-COVID-19, due to health consciousness.NGOs such as the Centre for Sustainable Agriculture have partnered with farmers to promote organic millet farming, increasing resilience and market access.

8. Conclusion

Millets are emerging as critical components of India's agricultural and nutritional strategies amidst growing climate uncertainties, environmental degradation, and malnutrition burdens. Once marginalized after the Green Revolution, millets are now being repositioned as "smart foods" — nutritious, climate-resilient, economically viable, and culturally significant. This review highlighted:

- Production and Consumption Trends: While millet production has seen resurgence, consumption is concentrated regionally, and urban markets are reviving demand.
- Nutritional Value: Millets outperform conventional cereals like rice and wheat in iron, calcium, dietary fiber, and glycemic properties, offering clear health benefits.
- Policy Landscape: Major policy shifts, including NFSM-Nutri-Cereals and IYOM-2023, signal renewed government commitment, though gaps remain in procurement, MSP coverage, and extension support.
- Climate and Ecological Benefits: Millets require less water, enrich soil health, sustain

biodiversity, and mitigate greenhouse gas emissions — making them vital for sustainable agriculture.

- Challenges: Productivity issues, market access, labor intensity, consumer perception, and infrastructural constraints still hinder millet mainstreaming.
- Regional Case Studies: Successful interventions in Odisha, Karnataka, Vidarbha, Bundelkhand, and Tamil Nadu show that millet promotion requires decentralized, localized, farmer-centric approaches.

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