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Origin and Agroecological Distribution of Millets: A Geographical Insight of India and World

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Abstract

Millets, a diverse group of small-seeded cereals, are among the earliest domesticated crops and continue to play a vital role in food security, especially in arid and semi-arid regions. Their global and regional distribution reflects not only agro-ecological suitability but also socio-cultural preferences and economic considerations. India remains the world's largest producer, contributing significantly to global millet cultivation, while Sub-Saharan Africa is equally prominent. This paper examines the geographical distribution of millets across the world with a focus on India, highlighting historical evolution, regional trends, ecological determinants, and policy implications. Drawing upon secondary data from FAO (2021, 2024), ICRISAT (2024), and peer-reviewed literature, this paper emphasizes the importance of millets in ensuring food and nutritional security, promoting sustainable agriculture, and supporting climate resilience. The study concludes that millet production and distribution are shaped by environmental, economic, and policy-driven factors, and that targeted interventions can enhance their role in global and regional food systems.

Key words: Millets, Agroecological distribution, Climate resilient crops, Nutritional security, Pearl millet.

Introduction

Millets have been cultivated for over 5,000 years and are considered one of humanity's ancient staple foods (4–5). They are small-grained cereals, including pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), proso millet (*Panicum miliaceum*), and little millet (*Panicum sumatrense*), among others. Unlike rice and wheat, millets are drought-resistant and thrive in poor soils, making them vital for food security in semi-arid and arid ecosystems (6–7).

Historically, millets have sustained ancient civilisations. Archaeobotanical evidence from the Yellow River basin in China, the Sahel region of Africa, and Neolithic sites in India confirms their domestication over 7,000 years ago (8). In India, millets were not only staple foods but also held ritualistic and medicinal significance, as documented in Vedic texts such as the *Yajurveda* and *Garuda Purana* (9). Despite their historical prominence, millet cultivation witnessed a decline during the Green Revolution, which prioritised high-yielding varieties of rice and wheat. This shift led to reduced millet acreage, loss of agro-biodiversity, and increased vulnerability to climate change.

The resurgence of interest in millets is driven by multiple factors. First, their nutritional profile is superior to many staple cereals. Millets are rich in iron, calcium, magnesium, dietary fibre, and bioactive compounds like flavonoids and phenolic acids, making them ideal for addressing micronutrient deficiencies and lifestyle diseases (10). Second, millets are climate-resilient crops. They require minimal water, tolerate drought and poor soils, and thrive in rainfed conditions, making them suitable for sustainable agriculture in marginal environments (11).India, as the largest producer of millets, has taken proactive steps to revive their cultivation. The declaration of 2023 as the International Year of Millets by the United Nations Food and Agriculture Organisation (FAO) catalysed global awareness and policy support (12). The Indian government launched the Millet Mission, integrated millets into the Public Distribution System (PDS), and promoted value addition through startups and farmer cooperatives. These initiatives aim to mainstream millets into national and global food systems.

Globally, India and Sub-Saharan Africa dominate millet production (1,13). However, despite their resilience, millet cultivation declined during the Green Revolution, when rice and wheat received more policy and market support (14). Recent decades have seen renewed interest in millets as "nutri-cereals," given their rich nutritional profile, health benefits, and climate resilience (10,15). The study conducted on 90 participants of type 2 diabetes concluded that if both the *Surya namaskar* and millets are intervened to diabetic patient, it plays a significant role in managing diabetes indicating that both physical activity (*Surya namaskar*) and diet (Little millets) will help managing the diabetes (16).This paper explores the origin and agroecological distribution of millets, with a geographical focus on India and comparative insights from global contexts. It integrates historical, ecological, and agronomic perspectives to understand how millets have adapted to diverse environments and how their cultivation patterns have evolved. The study also analyses recent data trends in millet production, area, and productivity, highlighting challenges and opportunities for future expansion.

Materials and Methods

This review synthesises existing literature and geospatial datasets to examine the origin and agroecological distribution of major millet species across India and globally. Historical domestication records were compiled from FAO, ICRISAT, ICAR, and peer-reviewed sources (1,3,17). Agroclimatic parameters including rainfall, temperature, elevation, and soil type were extracted from World Clim, ISRO, and NBSS&LUP databases (18). Seven millet species were considered: Finger, Pearl, Foxtail, Little, Barnyard, Proso, and Kodo millet. GIS platforms (ArcGIS, QGIS) were used to visualise spatial distribution and overlay ecological zones. India's agroecological zones were classified per ICAR guidelines; global zones followed FAO's AEZ framework. Descriptive statistics and cluster-based comparisons were applied to identify ecological groupings and cultivation trends. No primary field data were collected; all insights are derived from secondary sources.

Origin of Millets

Indian Origins: Archaeological and Literary Evidence

India's millet history is particularly rich, with evidence spanning the Neolithic, Chalcolithic, Harappan, and Iron Age periods. Millets were not only staple foods but also held ritualistic, medicinal, and symbolic significance in ancient Indian culture**.** Recent studies have mapped millet cultivation across key archaeological sites in India (19)**:**

Table 1: Showing Ancient Millets Sites in India

Site	Location	Millet Species Found	Period
Hallur	Karnataka	Finger millet, foxtail	Neolithic (2000 BCE)
Senuwar	Bihar	Barnyard millet	Chalcolithic (1500 BCE)
Harappa	Punjab	Sorghum, pearl millet	Harappan (2500 BCE)
Bhagimohari	Maharastra	Little millet	Iron Age (1000 BCE)
Raja-Nal-ka-Tila	Uttarpradesh	Foxtail, barnyard millet	Iron Age (500 BCE)

These findings confirm that millets were cultivated across diverse agroecological zones, from the Deccan plateau to the Indo-Gangetic plains (19). Millets are frequently referenced in classical Indian literature, underscoring their ritualistic, medicinal, and nutritional significance. The *Yajurveda* identifies *Shyamaka* (barnyard millet) as a consecrated grain employed in *yajnas* (sacrificial fire rituals) and associates it with Lord Soma, the lunar deity. The *Garuda Purana* attributes therapeutic properties to *Syamaka*, particularly in regulating bodily *doshas* and supporting digestive health. The *Charaka Samhita* recommends the inclusion of millets in the management of metabolic disorders and in enhancing immune function. Similarly, the *Agni Purana* describes the ritual placement of millets during ceremonial bathing festivals, reflecting their symbolic role in religious practice. Collectively, these sources illustrate an advanced understanding of the nutritional and curative potential of millets, as well as their embeddedness in cultural and spiritual traditions (20).

Global Origins and Domestication Pathways

Finger millet is believed to have originated in East Africa before spreading to India (5). These diverse origins explain why millet cultivation is still concentrated in Africa and Asia today (14). Millets underwent independent domestication across several regions, notably Africa, East Asia, and Europe, with each area contributing unique species shaped by specific agroecological settings and cultural dietary patterns below given Table 3. Showing Global Agroecological Spread confirms that In Africa, Pearl millet (*Pennisetum glaucum*) is thought to have originated in the Sahel, particularly in present-day Niger and Mali, around 3000 BCE. Archaeobotanical discoveries from sites such as Dhar Tichitt in Mauritania and Gobero in Niger provide evidence of its early cultivation in arid landscapes, where its drought resilience facilitated its establishment as a cornerstone of subsistence farming systems in West Africa (21). In China, Foxtail millet (*Setaria italica*) and Broomcorn millet (*Panicum miliaceum*) were domesticated in the Yellow River basin by approximately 6000 BCE. Excavations at Cishan and Peiligang revealed millet remains in storage pits and cooking vessels, underscoring their importance in Neolithic diets (8). These crops not only supported early settled agriculture but were also commonly intercropped with legumes. In Europe, Proso millet (*Panicum miliaceum*) was cultivated from the Bronze Age onward, particularly in Central Europe. Archaeological records from Austria, Hungary, and Germany document its presence in burial contexts and ceramic assemblages, suggesting both dietary and ritual significance. Its short maturation period and adaptability to temperate environments enhanced its value as a staple crop (22).

Table 2: Showing Global Agroecological Spread

Region	Dominant Millet(s)	Agroecological Traits	Key Countries
West Africa	Pearl millet	Arid, Sahelian belt, sandy soils	Niger, Mali, Nigeria
East Asia	Foxtail, Broomcorn millet	Temperate zones, loess soils	China, Mongolia
Central Europe	Proso millet	Continental climate, mixed cropping	Hungary, Austria, Germany
Southeast Asia	Finger, Little millet	Tropical climate, high humidity	India, Nepal, Myanmar
Latin America	Introduced millets	Marginal lands, niche health markets	Brazil, Mexico

Aarchaeological records from Austria, Hungary, and Germany document its presence in burial contexts and ceramic assemblages, suggesting both dietary and ritual significance. Its short maturation period and adaptability to temperate environments enhanced its value as a staple crop (22). Globally, millets are cultivated across Africa, Asia, and parts of Europe and the Americas. Their distribution is influenced by climatic zones, soil types, and socio-economic factors. Millets are often grown in regions where other cereals fail, making them essential for food security in vulnerable agroecosystems.

Agroecological distribution of millets in India and the World

Millets are uniquely adapted to thrive in diverse agroecological zones, particularly in regions characterized by low rainfall, poor soil fertility, and high temperatures. Their distribution reflects both ecological suitability and cultural preferences, shaped by centuries of localized farming practices. This section examines the spatial spread of millet cultivation across India and globally, supported by recent data and geographical insights.

Agroecological Zones of India

India's agroecological diversity ranging from arid deserts to humid tropics has enabled the cultivation of multiple millet species. According to Warisa et al. (2025), millets are predominantly grown in semi-arid and arid regions, where they outperform other cereals in terms of yield stability and resource efficiency (24). Below given Table Shows the Major Millets Growing Regions in India according to climatic factors.

Table 3: Showing Major Millets Growing Regions in India

State/Region	Dominant Millet(s)	Agroecological Features	Rainfall (mm/year)	Soil Type
Rajasthan	Pearl millet (*Bajra*)	Arid zone, high temperature, sandy soils	100-400	Sandy loam
Karnataka	Finger millet (*Ragi*)	Red loamy soils, moderate rainfall	600–900	Red loam
Tamilnadu	Barnyard, little millet	Semi-arid, mixed cropping systems	500–800	Clay loam
Maharastra	Sorghum, pearl millet	Dryland farming, low-input agriculture	400–700	Black cotton soil
Uttarakhand	Barnyard, finger millet	Hill farming, terraced fields	800–1200	Mountain loam
Odisha	Foxtail, kodo millet	Tribal regions, shifting cultivation	1000–1400	Lateritic soil

These regions reflect millet's adaptability to marginal environments and its role in traditional cropping systems.

Geographical Distribution of Millets in India

India has cultivated millets for thousands of years, with evidence dating back to the Harappan civilisation (20). Traditionally, millets were a staple food across semi-arid regions before being gradually displaced by rice and wheat after the Green Revolution (14). Despite this decline, India still remains the world's largest producer of millets (2). Western India Rajasthan: The state which leads in pearl millet (bajra) production and contributes about 40% of the domestic production. It is cultivated in semi-arid and arid areas with little rainfall (3). Gujarat and Maharashtra: both states produce pearl millet and sorghum. While Maharashtra also contributes to finger millet (ragi) production, it is also cultivated in the Konkan and Western Ghats (25). Southern India Karnataka: The most productive finger millet producer and contributing nearly 60% of domestic ragi production (6). Tamil Nadu and Andhra Pradesh: Crop production of small millets such as kodo, little and foxtail. These states have a history of using millets in their traditional diets such as idlis and dosas with ragi and foxtail millet (10). Central India Madhya Pradesh and Chhattisgarh: Important for Kodo millet and little millet, mostly grown by tribal farmers (14). These areas follow rain fed farming, in which millets enhance climate resilience. Northern India Uttar Pradesh and Haryana: Pearl millet is important in western Uttar Pradesh and is grown on a small scale in Haryana. Both regions integrate millet with mixed cropping (25). Eastern and North Eastern India Odisha and Jharkhand: Grown for finger millet and small millets in tribal and hilly regions. Northeastern states (Nagaland, Manipur, Mizoram, and Assam): Barnyard millet and foxtail millet grown in shifting cultivation (jhum) systems contribute to dietary diversity (26**).**

Recent data trend and analysis

According to the Ministry of Agriculture & Farmers' Welfare (2022), millets are cultivated on nearly 12–13 million hectares in India, with annual production between 15–18 million tonnes. Pearl millet, finger millet, and sorghum dominate production, while small millets such as Kodo, Little, Barnyard, and Foxtail are regionally significant. Banerjee et al. (2024) present a comprehensive analysis of millet cultivation in India. In 2022–23, millets were grown on approximately 14.5 million hectares, with Pearl millet occupying the largest proportion. The overall production was estimated at 17.3 million tonnes, with Finger millet and Sorghum contributing substantially. Between 2012 and 2023, average productivity increased from 1,149 kg/ha to 1,308 kg/ha, a trend attributed to the adoption of improved agronomic practices and hybrid varieties. Export volumes expanded by 22% from 2020 to 2024, largely driven by rising demand in Europe and North America. Forecasts based on ARIMA modelling suggest that the area under Sorghum will contract from 3.5 million hectares in 2022–23 to 2.4 million hectares by 2030; however, productivity is projected to improve owing to superior cultivars and enhanced crop management (27).

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Globally, millets are cultivated on about 30 million hectares, with production ranging from 28–32 million tonnes annually (1–2). The principal millet-producing regions are geographically diverse. In Sub-Saharan Africa, nations such as Nigeria, Niger, Mali, and Sudan are prominent producers of pearl millet, where the crop constitutes a dietary staple and is traditionally processed into porridges, flatbreads, and fermented beverages (1,3). Within South Asia, India contributes over 40% of the global millet area and nearly one-fifth of total production, primarily through the cultivation of pearl millet and finger millet (6). Smaller-scale production is also observed in Nepal and Pakistan. In East Asia, China continues to play a significant role in foxtail and proso millet production, although output has declined as cultivation has shifted toward rice and wheat (8). Beyond these regions, countries such as the United States, Russia, and several European nations produce proso millet largely for birdseed and specialized markets (23).

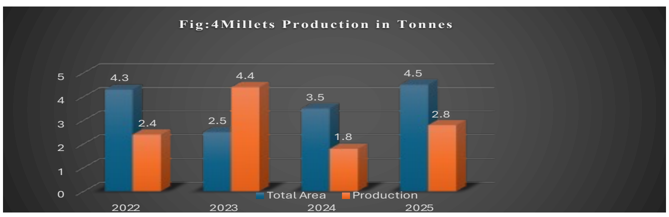
ICRISAT (2024) highlights that global millet production remains predominantly concentrated in Africa, where countries such as Nigeria, Niger, and Mali serve as major centres of pearl millet cultivation. In Asia, China and India hold a leading position in the production of foxtail and finger millet. Conversely, in Europe and the Americas, millet cultivation is confined to specialised markets, primarily catering to health-conscious consumers and the demand for gluten-free products. Despite a reduction of nearly 60% in global millet acreage over the past seven decades, overall productivity has increased by approximately 200%, underscoring the transition toward more intensive cultivation systems and the widespread adoption of improved varieties (28). Unlike rice or wheat, millet trade is relatively small and regionally concentrated. Africa and India account for most consumption, often in subsistence farming systems (25). International trade is minor, although niche markets for gluten-free products are emerging in Europe and North America (10,1).

India Area, Production and Yield (2022- 2025)

Based on the latest data from (Warisa et al., 2025). Table 4. Showing Millets Year Wise Data for Area, Production and Average Yield confirms that area, production and average yield per year increased and it was estimated 1380 Kg/ha for 2025.

Table 4: Showing Millets Year Wise Data for Area, Production and Average Yield

Year	Total Area	Production	Average
2022	14.2	16.8	1183
2023	14.5	17.3	1308
2024	14.7	17.9	1354
2025	15.1 (est.)	18.6 (est.)	1380 (est.)



Pearl millet accounts for ~40% of total millet area. *Finger millet* shows highest yield (~1800 kg/ha) due to improved varieties and agronomic practices.

Global Production Snapshot

According to FAO and ICRISAT (2024), regional patterns of millet cultivation vary significantly. Africa accounts for approximately 60% of global Pearl millet production, while in Asia, India and China dominate the cultivation of finger and foxtail millet. In Europe, Proso millet is primarily grown for bird feed and specialised health-conscious markets. Across the Americas, millet cultivation is gradually expanding, particularly within organic and gluten-free sectors. Although global millet acreage has declined over the past five decades, productivity levels have risen, largely owing to the development of improved cultivars and advances in mechanisation. Millets provide multiple agroecological benefits. Their deep-rooted systems enhance soil structure and help mitigate erosion, thereby contributing to long-term soil health. They are also highly water-efficient, requiring 30–70% less water compared to staple crops such as rice and wheat. In terms of environmental impact, millet cultivation is associated with a lower carbon footprint, largely due to reduced reliance on chemical fertilisers. Furthermore, integrated nutrient management practices incorporating organic amendments, biofertilisers, and minimal chemical inputs have been shown to enhance both crop yields and soil fertility (24).

Ecological and Nutritional significance of Millets

Millets are increasingly recognised as "smart foods" due to their dual role in promoting human health and ecological sustainability. Their resilience to climate stressors, minimal input requirements, and rich nutritional profile make them ideal candidates for sustainable agriculture and functional nutrition. This section explores the ecological advantages of millet cultivation and their biochemical composition, highlighting their relevance in addressing global challenges such as malnutrition, climate change, and soil degradation. Millets thrive in agroecological regions where the cultivation of other cereals is often unsuitable, offering distinct advantages in terms of environmental sustainability. Climate resilience is one such attribute, as millets can withstand extreme conditions including high temperatures of up to 45°C, irregular rainfall, and prolonged droughts. They also require 30–70% less water than rice or wheat, making them particularly well-suited for rainfed agriculture (29). With respect to soil health and biodiversity, the deep root systems of millets improve soil structure and reduce erosion. Their frequent use in mixed cropping systems enhances agro-biodiversity, supports natural pest regulation, promotes pollinator diversity, and helps sustain ecological balance on marginal lands (30). Furthermore, in terms of carbon emissions, millet cultivation has a lower environmental footprint owing to minimal water and fertilizer requirements. Life cycle

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assessments indicate that millet systems emit 40–60% less CO_2 compared to rice and wheat production (31).

Nutritional Composition and Biochemical Profiles

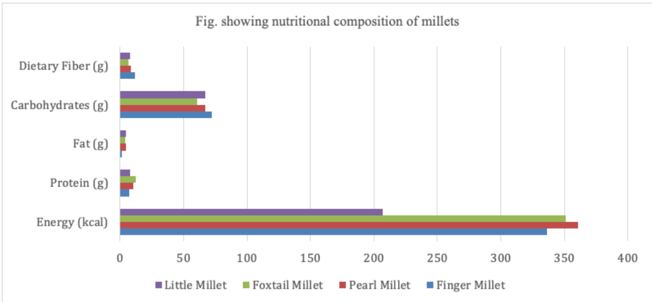
Millets are nutrient-dense grains packed with macro- and micronutrients, bioactive compounds, and dietary fiber. Their composition varies across species and cultivars, but common nutritional highlights include:

Table 5: Showing Nutritional Composition of Major Millet Per 100g

Nutrient	Finger	*Pearl*	Foxtail	Little
Energy (kcal)	336	361	351	207
Protein (g)	7.3	10.6	12.3	7.7
Fat (g)	1.3	4.8	4.3	4.7
Carbohydrat	72.6	67.0	60.9	67.0
Dietary Fiber	11.5	8.5	6.7	7.6

(Source: Sharma et al., 2021; Dhiman et al., 2025)

Figure 1: Nutritional Composition of Major Millets



Millets are rich in essential micronutrients and bioactive compounds that enhance their nutritional and functional value. Fig.2. Shows Nutritional Composition of Major Millet Per 100g Iron content in finger millet can reach up to 3.9 mg per 100 g, playing an important role in the prevention of anaemia. Calcium levels are particularly high, with finger millet containing approximately 344 mg per 100 g nearly ten times greater than that found in rice. Additionally, magnesium and zinc are present in considerable amounts, contributing to key metabolic processes. Millets also contain phenolic acids and flavonoids, which function as antioxidants, alleviating oxidative stress and inflammation. Furthermore, phytosterols support cardiovascular health by lowering LDL cholesterol. Collectively, these nutritional and bioactive components position millets as functional foods with promising applications in nutraceutical development (33).

Health benefits and disease prevention

Extensive clinical and epidemiological research highlights the diverse health benefits of millets. In terms of glycemic control, their low glycemic index makes them particularly appropriate for individuals with diabetes. Regarding cardiovascular health, the high fiber and phytosterol content of millets contributes to the regulation of blood pressure and lipid metabolism. They also play a role in weight management, as their fiber content promotes satiety and slows digestion, thereby reducing obesity risk. For gut health, the prebiotic properties of millets enhance gut microbiota composition and improve digestive function. Moreover, owing to their naturally gluten-free composition, millets are considered safe for individuals with celiac disease or gluten intolerance (31,34).

Sustainability and distribution drivers of millets

Millets exhibit superior sustainability metrics compared to rice and wheat, requiring significantly less water (1,200–2,000 L/kg), emitting lower greenhouse gases (0.5–0.9 kg CO_2 eq), and demanding minimal fertilizer input (20–40 kg/ha), with low soil erosion risk.

Table 6: Showing Comparative Sustainability Metrics

Parameter	Millets	Rice	Wheat
Water Requirement (L/kg)	1,200–2,000	3,000–5,000	2,500–4,000
GHG Emissions (kg CO_2 eq)	0.5–0.9	1.5–2.3	1.2–1.8
Fertilizer Use (kg/ha)	20–40	80–120	60–100
Soil Erosion Risk	Low	High	Moderate

Their agroecological adaptability to arid, semi-arid, and marginal ecosystems such as sandy soils in Rajasthan and lateritic soils in southern India supports widespread cultivation in drought-prone regions of India and Sub-Saharan Africa. Socio-cultural traditions, particularly in Karnataka, Tamil Nadu, and parts of Africa, have sustained millet consumption despite limited institutional support. Economically, millets thrive on marginal lands but face challenges due to weak market infrastructure and low consumer demand, although recent health trends have revived interest in gluten-free millet products. Policy recognition, including India's National Year of Millets (2018) and the UN's International Year of Millets (2023), has catalyzed institutional support through PDS inclusion and global initiatives by FAO and ICRISAT. As climate-smart crops, millets offer resilience against erratic rainfall, high temperatures, and degraded soils, positioning them as vital components of future food and climate adaptation strategies (24,12).

Discussion

Globally, millet cultivation is concentrated in Africa and Asia, reflecting their historical domestication centres (8,14). In Africa, Pearl millet dominates, while in India, both Pearl millet and finger millet are significant. East Asia remains important for foxtail millet, although production has declined in China due to dietary shifts (8). India's role is particularly noteworthy: it alone accounts for nearly half of global millet area and about 20% of production (1). Within India, regional diversification is striking—Rajasthan for Pearl millet, Karnataka for finger millet, and tribal states for small millets (6). This diversity underscores the ecological adaptability of millets and their embeddedness in local food systems. Despite their resilience, millet production faces several challenges: Declining acreage: The Green Revolution prioritized rice and wheat, leading to a systematic decline in millet area (14). Low market demand: Urban consumers often prefer polished rice and refined wheat flour, marginalizing traditional grains (15). Policy neglect: Procurement, subsidies, and research investments remain skewed toward rice and wheat (25). Trade limitations: Unlike rice and maize, millets play a minimal role in international trade (2).

On the other hand, the current global discourse on nutrition and climate resilience offers significant opportunities: Nutritional benefits: Millets are rich in dietary fiber, iron, zinc, and calcium, making them important for combating malnutrition and lifestyle diseases (10). Climate adaptation: Their tolerance to drought and heat makes millets vital for climate-smart agriculture (7). Policy support: Initiatives like the International Year of Millets (2023) and India's inclusion of millets in public distribution and mid-day meal schemes represent major policy shifts (12). Emerging markets: Growing demand for gluten-free and functional foods in Western countries provides opportunities for millet exports (15). The study conducted by Rajesh et al. (2024) the findings from this study, along with existing research, highlight the immunomodulatory potential of finger millet. The differences in their effects on immune stimulation or inhibition suggest that they may exert their actions through various mechanisms. The findings pave the way for further exploration of finger millet's role in nutritional immunology and its application in developing novel immunomodulatory interventions (35). Furthermore, millet agronomy and nutrition have been widely studied, gaps remain in areas such as: Processing technologies to improve shelf-life and consumer acceptance. Economic incentives for farmers in marginal regions. Climate modeling to predict future millet suitability. Integration of millets into global trade systems (6,25).

Conclusion

Millets, among the world's most ancient domesticated crops, remain vital for ensuring food and nutritional security in regions vulnerable to climate change. Their geographical distribution highlights their ecological resilience and cultural embeddedness: *pearl millet* thrives in the arid zones of Africa and Rajasthan, finger millet dominates Karnataka and East Africa, and small millets persist in tribal and hilly regions across India and Southeast Asia.

Globally, millet cultivation faces challenges of declining acreage, policy neglect, and weak market systems, yet the nutritional and ecological advantages of these crops present unique opportunities for revival. India's position as the largest producer places it at the center of global millet discourse, especially after the declaration of 2023 as the International Year of Millets.

Moving forward, strengthening policy support, improving value chains, and enhancing consumer awareness are essential to integrate millets into sustainable food systems. Research must also bridge technological and economic gaps to ensure that millets contribute meaningfully to addressing hunger, malnutrition, and climate resilience in the 21st century.

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