AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 07 (July, 2026)
Available online at http://www.agrimagazine.in

Millets on the Mountains: Sustainable Cropping Systems for Climate Resilient Agriculture in India's Hilly Regions

*Bhokre Suresh[1], G. Narendar[2] and Badigi Pavan Naik[3]
[1]Ph.D. Scholar, Department of Agricultural Economics, College of Agriculture, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha, India
[2]Ph.D. Scholar, Department of Agronomy, College of Agriculture, OUAT, Bhubaneswar-751003, Odisha, India
[3]Ph.D. Scholar, Department of Extension Education, College of Agriculture, OUAT, Bhubaneswar-751003, Odisha, India
*Corresponding Author's email: sureshbhokremau@gmail.com

India's hilly regions, from the Himalayas to the Eastern and Western Ghats, support millions of farmers battling shallow soils, erratic rainfall, and worsening climate stress. This article explores how reviving millet-based cropping systems offers a practical, climate-resilient path forward for these fragile landscapes. Hardy species such as finger, barnyard, foxtail, little, and pearl millet need little water, tolerate poor soils, and pack dense nutrition, making them natural allies for mountain farming. Paired with legumes like pigeon pea, lentil, and black gram through intercropping and rotation, millets restore soil fertility, check erosion, and conserve scarce water while opening new income streams. Beyond the field, they tackle hidden hunger, delivering calcium, iron, and fibre vital for rural diets. With growing government support and rising market demand for millet products, these ancient grains are re-emerging as a smart solution, proving that some of farming's oldest crops hold the answers to its newest challenges.

Introduction

The hilly regions of India are home to millions of small and marginal farmers whose livelihoods depend on rainfed agriculture. These regions, stretching across the Himalayas, the North Eastern Hills, the Eastern Ghats, and the Western Ghats, are characterized by undulating terrain, fragile ecosystems, shallow soils, erratic rainfall, and limited irrigation facilities. Climate change has further intensified the challenges of farming in these landscapes through unpredictable rainfall, prolonged dry spells, increased soil erosion, and declining soil fertility. Under such circumstances, the need for sustainable and climate-resilient agricultural systems has become more urgent than ever.

One of the most promising solutions lies in the revival and promotion of millet-based cropping systems. Millets have been cultivated in India for thousands of years and were traditionally known as the "smart foods" of rural communities. They require minimal water, thrive in poor soils, withstand drought and temperature fluctuations, and offer exceptional nutritional value. Their adaptability makes them particularly suitable for the hilly regions where conventional cereal crops often fail to provide stable yields. The declaration of 2023 as the International Year of Millets by the United Nations, following India's proposal, has renewed global attention toward these ancient grains. Today, millets are increasingly recognized not only as nutritious foods but also as key crops for climate-smart agriculture and sustainable farming systems.

Why Millets are Ideal for Hilly Agriculture

Unlike water-intensive crops such as rice and wheat, millets are naturally adapted to marginal environments. Their extensive root systems enable them to extract moisture from deeper soil layers, making them highly tolerant of drought. Most millet species can complete their life cycle with 300–500 mm of rainfall, significantly less than many cereal crops. The hilly regions of India frequently experience shallow soils with low fertility. Millets can produce reasonable yields even under these conditions because they efficiently utilize available nutrients and require comparatively lower fertilizer inputs. Their shorter duration also allows farmers to fit them into multiple cropping systems, improving land-use efficiency. Another significant advantage is their resilience to climate variability. With increasing instances of erratic monsoons, heat stress, and moisture scarcity, millet cultivation provides greater production stability compared with many traditional cereals. This resilience reduces the risk of complete crop failure and enhances food security for farming households. Nutritionally, millets are rich in dietary fiber, calcium, iron, zinc, antioxidants, and essential amino acids. Finger millet, for example, contains exceptionally high calcium content, while little millet and foxtail millet are excellent sources of iron and dietary fiber. Thus, millet cultivation contributes simultaneously to agricultural sustainability and nutritional security.

Diversity of Millets Suitable for Hill Regions

India possesses remarkable diversity in millet cultivation, with different species adapted to varying elevations and agro-climatic conditions. Finger millet (Ragi) is the most widely cultivated millet in many hill regions. It performs exceptionally well in medium elevations and is highly valued for its nutritional richness and storage quality. Barnyard millet thrives in high-altitude environments and has one of the shortest crop durations among cereals, making it suitable for short growing seasons. Foxtail millet is drought tolerant and suitable for rainfed farming in both lower and middle hill ecosystems. Little millet performs well under poor soil conditions and is highly resistant to pests and diseases. Pearl millet is generally cultivated in lower hill regions with relatively warmer climates and serves as both a food and fodder crop. Together, these millets provide flexibility for farmers to select species according to local environmental conditions.

Millet-Based Cropping Systems: A Sustainable Approach

Cropping systems determine the long-term sustainability of agricultural production. Instead of cultivating a single crop repeatedly, diversified cropping systems combine cereals with legumes, oilseeds, vegetables, or fodder crops to improve productivity and soil health. Millet-based cropping systems are particularly effective because millets complement other crops in terms of nutrient use, water requirements, and growth duration.

Finger Millet + Pigeon Pea

One of the most successful intercropping systems involves finger millet with pigeon pea in an 8:2 row ratio. While finger millet provides grain yield, pigeon pea fixes atmospheric nitrogen through biological nitrogen fixation, thereby enriching soil fertility. The deep-rooted pigeon pea also improves soil structure and reduces erosion.

Finger Millet–Mustard Rotation

After harvesting finger millet during the kharif season, farmers can cultivate mustard during the rabi season using residual soil moisture. This cropping sequence enhances land-use efficiency and provides an additional source of income.

Foxtail Millet–Lentil System

Foxtail millet followed by lentil improves soil fertility while diversifying farm production. Lentils contribute nitrogen to the soil and reduce fertilizer requirements for subsequent crops.

Little Millet + Black Gram

Intercropping little millet with black gram effectively suppresses weeds, improves soil fertility, and provides balanced household nutrition through cereal-legume combinations.

Barnyard Millet–Pea Rotation

In high-altitude regions, barnyard millet followed by pea efficiently utilizes available moisture and extends productive use of agricultural land.

Millet–Vegetable Systems

Terrace farming in hilly areas provides opportunities to integrate seasonal vegetables with millets. Such diversification substantially increases farm income while improving dietary diversity.

Soil Health Improvement through Millets

Healthy soils form the foundation of sustainable agriculture. Unfortunately, soil erosion remains one of the biggest challenges in hilly agriculture, often resulting in nutrient loss and declining productivity. Millets contribute to soil conservation in several ways. Their fibrous root systems bind soil particles, reducing erosion caused by rainfall and surface runoff. Crop residues left after harvest serve as protective mulch, reducing evaporation and preventing nutrient loss. Continuous incorporation of crop residues enhances soil organic carbon, improves soil structure, and increases water-holding capacity. When combined with legumes such as pigeon pea, cowpea, black gram, or chickpea, millet-based systems naturally replenish soil nitrogen through biological fixation. Long-term adoption of diversified millet-based systems therefore improves soil fertility while reducing dependence on chemical fertilizers.

Water Conservation in Hill Farming

Water scarcity is becoming increasingly common in many hilly regions due to changing rainfall patterns. Sustainable millet production relies on efficient water management practices. Contour bunding slows rainwater runoff and enhances infiltration into the soil. Terracing reduces erosion while increasing moisture retention. Mulching with crop residues conserves soil moisture and suppresses weeds. Rainwater harvesting structures such as farm ponds store excess monsoon rainfall for supplemental irrigation during dry spells. Because millets require considerably less water than rice or maize, they naturally complement these water conservation practices.

Integrated Nutrient Management

Balanced nutrient management is essential for maintaining productivity without degrading natural resources. Farmyard manure remains the backbone of nutrient management in traditional hill farming. Compost and vermicompost improve microbial activity and increase soil organic matter. Green manuring enriches soil fertility while reducing fertilizer costs. Biofertilizers such as Azotobacter and phosphate-solubilizing bacteria enhance nutrient availability and improve root development. Chemical fertilizers should be applied only according to soil test recommendations to prevent nutrient imbalance and environmental pollution. An integrated nutrient management approach combines organic and inorganic sources for sustainable productivity.

Integrated Pest and Disease Management

Millets generally suffer from fewer pest and disease problems than many major cereals. Nevertheless, integrated pest management further minimizes crop losses while reducing pesticide dependence. Farmers can install bird perches to encourage natural predators, use neem-based botanical pesticides, cultivate resistant varieties, maintain field sanitation, and rotate crops regularly. Crop diversification itself reduces pest outbreaks by interrupting pest life cycles and improving ecosystem balance.

Climate Change and Millets

Climate change poses unprecedented challenges to agriculture. Rising temperatures, irregular rainfall, and increasing frequency of droughts threaten food production across India. Millets offer one of the strongest natural adaptations to these changing conditions. They require less irrigation, tolerate heat stress, survive temporary moisture deficits, and maintain stable yields

under variable climates. Their short growing periods also allow farmers to escape late-season droughts. Consequently, millet-based farming systems are increasingly regarded as climate-smart agriculture capable of enhancing resilience among vulnerable farming communities.

Economic Benefits for Farmers

Millet cultivation provides several economic advantages beyond grain production. Input costs are generally lower because millets require fewer fertilizers, pesticides, and irrigation. Crop diversification generates multiple sources of income through grains, pulses, vegetables, fodder, and oilseeds. Growing consumer demand for nutritious foods has increased market opportunities for value-added millet products such as flour, biscuits, noodles, breakfast cereals, ready-to-cook mixes, and health foods. Women self-help groups and farmer producer organizations can significantly enhance rural livelihoods through millet processing and marketing.

Nutritional Security

Hidden hunger caused by micronutrient deficiencies remains a major public health concern. Millets contribute substantially toward improving dietary quality because they are rich in calcium, iron, zinc, magnesium, antioxidants, and dietary fiber. Finger millet is particularly beneficial for children, pregnant women, and elderly people because of its exceptionally high calcium content. Regular millet consumption has been associated with improved glycemic control, cardiovascular health, and digestive health. Therefore, millet-based agriculture supports both food security and nutritional security.

Policy Support and Future Prospects

Government initiatives promoting natural farming, organic agriculture, climate-resilient agriculture, and millet value chains have created new opportunities for hill farmers. Research institutions continue to develop improved millet varieties with higher yields, disease resistance, and better nutritional quality. Mechanization suitable for hill agriculture, improved post-harvest processing technologies, and strengthened market linkages can further accelerate millet adoption. Farmer training on sustainable cropping systems, water conservation, integrated nutrient management, and value addition will be essential for realizing the full potential of millet-based agriculture.

Conclusion

Millets represent far more than traditional grains; they symbolize resilience, sustainability, and nutritional well-being. Their remarkable adaptability to harsh environments makes them ideal crops for India's fragile hill ecosystems. When integrated with legumes, oilseeds, vegetables, and conservation agriculture practices, millet-based cropping systems improve soil fertility, conserve water, reduce erosion, diversify income, and strengthen climate resilience. As India strives toward sustainable agriculture and food security, millet-based farming offers a practical pathway for transforming hill agriculture. Reviving these ancient crops through scientific management, farmer participation, supportive policies, and market development will ensure healthier ecosystems, prosperous farming communities, and nutritious diets for future generations.

References

1. ICAR's work on millet research and production technologies
2. The Indian Institute of Millets Research's annual reports on millet production
3. The FAO's coverage of the International Year of Millets, 2023
4. The Ministry of Agriculture and Farmers Welfare's National Food Security Mission on Nutri-Cereals
5. NITI Aayog's strategy papers on sustainable agriculture in India
6. ICRISAT's research on millets for climate-resilient agriculture
7. The United Nations' Global Initiative on Millets
8. NICRA's resources on climate-resilient agricultural practices