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Millet-Based Cropping Systems: Implications for Climate Resilience and Sustainable Agriculture

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Millets are emerging as critical components of climate-resilient and sustainable agricultural systems due to their adaptability, low input requirements, nutritional benefits, and compatibility with diversified cropping systems. This review synthesizes current knowledge on the performance, resilience, ecological advantages, and sustainability potential of millet-based cropping systems. Evidence from recent studies indicates that millets can play a significant role in mitigating the adverse effects of climate change, enhancing food and nutritional security, and improving farmer livelihoods, particularly in rainfed and resource-limited agroecosystems. Policy support, value-chain development, and climate-smart agronomy are essential for scaling millet based systems globally.

Introduction

Millets are C4 cereals characterized by high photosynthetic efficiency, short crop duration, and remarkable tolerance to heat and drought. Historically labelled as "coarse cereals" or "orphan crops", millets are now re-positioned as Nutri-cereals. Among thirteen species in millets, sorghum (Sorghum bicolor L.) and pearl millet (Pennisetum typhoides L.) are considered as major, while finger millet (Eleusine coracana L.), barnyard millet (Echinochloa frumentacea L.), foxtail or Italian millet (Setaria italica L.), Kodo millet (Paspalum scrobiculatum L.), little millet (Panicumsumatrens L.) and prosomillet (Panicum miliaceum L.) are smaller millets. They are known to be low in dietary bulk, high in nutrient content and known for its good profile of amino acids. Millets are highly nutritious and has antioxidant properties which provides balanced nutrition (Mishra et al., 2014). Agriculture globally is facing multiple vulnerabilities arising from climate change, including drought, heat stress, erratic rainfall patterns, and declining soil health. Traditional cereal crops such as rice and wheat are highly sensitive to these stresses due to their high water and input requirements. In contrast, Millet cultivation requires fewer external inputs such as fertilizers, pesticides, and irrigation, resulting in lower energy consumption and greenhouse gas emissions. Thus, millet-based systems contribute to climate change mitigation (Pretty et al., 2018). Moreover, they are more resilient to climate change than most other cereal crops. In light of these challenges, the adoption of millet based cropping system for a sustainable and climate resilient agriculture millet cultivation is emerging as a promising option.

Millet-Based Cropping Systems

Millet-based cropping systems are farming systems where millets (like pearl millet, finger millet, foxtail, little, kodo, barnyard millets) are grown either alone, in rotation, or intercropped with legumes, oilseeds, vegetables, or trees. Intercropping improves resource-use efficiency, reduces production risk, and enhances overall system productivity (Lithourgidis et al., 2011). Sequential cropping systems involving millets followed by pulses or oilseeds optimize land use and enhance resilience to erratic rainfall. Crop rotations with

millets help in breaking pest cycles, improving soil structure, and sustaining productivity (Sharma et al., 2020).

These systems are especially important for dryland and climate-stressed regions because millets tolerate drought, poor soils, and high temperatures while providing nutritious grain and fodder. It may include:

- Sole millet cropping (pure stand of one millet),
- Millet + legume/pulse intercropping (e.g., pearl millet + cowpea, finger millet + black gram),
- Millet + oilseed/vegetable intercropping (e.g., millet + groundnut, millet + vegetable cowpea)
- Millet-based crop rotations (e.g., finger millet–pigeon pea, pearl millet–chickpea)
- Millet-based agroforestry / integrated farming systems (millets with fruit trees, livestock, etc.).

In India, millet-based cropping systems are widely practiced in states such as Rajasthan, Maharashtra, Karnataka, Telangana, Andhra Pradesh, Tamil Nadu, Odisha, Madhya Pradesh, Gujarat, Jharkhand, and Chhattisgarh, covering arid, semi-arid, and sub-humid tropics. Pearl millet and sorghum dominate the arid and semi-arid regions of western and central India, while finger millet and small millets are common in the southern peninsula, Eastern Ghats, and tribal regions with undulating terrain and marginal soils (Rai et al., 2018).

Climate Resilience Traits Of Millets

Millets are hardy crops that require comparatively low moisture and are capable of withstanding high temperatures, tolerating heat levels of up to 42 °C. They have a short growth duration, generally ranging from 45 to 120 days, which enables them to escape adverse climatic conditions. Millets are predominantly cultivated during the kharif season, though they are also grown during summer and rabi under both rainfed and irrigated environments.

The climate adaptability of millets is largely attributed to their physiological characteristic traits that confer drought tolerance, including deep root systems, high water-use efficiency, reduced transpiration losses, and osmotic adjustment mechanisms. Being C_4 plants, millets exhibit superior water use efficiency and nitrogen use efficiency, allowing them to maintain productivity under moisture-limited conditions (Gupta et al.). In addition, millets possess inherent resistance to several pests and diseases, further enhancing their resilience. Compared to rice and wheat, millets exhibit greater yield stability under rainfall variability and temperature extremes. Their ability to withstand climatic shocks makes them reliable crops for smallholder farmers in dryland regions (Krishnamurthy et al., 2014).

Pearl millet is drought resistant which is developed through its rooting system, water use efficiency, leaf adaptations etc. Shrestha et al. Sorghum developed drought tolerance through extensive root system and tolerance of water potential decrease (Tari et al). Both pearl millet and sorghum are heat tolerant crops and are grown in semi-arid regions (Rai et al). Finger millets are also been documented to perform well in extreme climate conditions (Gupta et al).

Role of Millet-Based Systems In Sustainability

Millet-based cropping systems support sustainability by using less water and chemicals, improving soil health, enhancing climate resilience, and diversifying both production and diets.

Key sustainability benefits

- **Low resource use**
  - ✓ Millets need much less water than rice and wheat, often growing well on rainfall alone in semi-arid areas.
  - ✓ They generally require fewer synthetic fertilizers and pesticides, lowering production costs and reducing chemical loads on soil and water.
- **Climate resilience and low emissions**

- Millets withstand high temperatures, erratic rainfall, and degraded soils, reducing chances of crop failure under climate change.
- Grown under non-flooded conditions, millets emit negligible methane compared with flooded rice; partial replacement of rice/maize by millets in India could cut greenhouse gas emissions by tens of millions of tonnes of CO_2-equivalent by 2050.

Soil health, biodiversity and Carbon Sequestration

- Millet cropping adds root biomass and crop residues that improve soil organic matter, structure, and water-holding capacity.
- Incorporating millets into rotations and intercropping systems enhances soil biological activity and agro-biodiversity, breaking pest and disease cycles.
- Millet-based systems contribute to soil organic carbon buildup, improved soil aggregation, and enhanced microbial activity. Their extensive root systems aid in nutrient cycling and carbon sequestration (Ghosh et al., 2012).

Water and Energy Use Efficiency

Millets require significantly less water and external inputs compared to irrigated cereals, making them energy-efficient and environmentally sustainable. This low input demand results in reduced greenhouse gas emissions (Pretty et al., 2018).

Farmer livelihoods and social sustainability

- Millets fit well into low-input, smallholder systems in rainfed areas, lowering risk and stabilizing income under climate stress.
    - Policy initiatives in India, such as promotion under the National Food Security Mission and state programmes like Odisha Millets Mission, are reviving millet value chains and improving market opportunities.

Conclusion

Overall, millet-based cropping systems represent a holistic solution for achieving climate resilience and agricultural sustainability. Strengthening research on improved varieties, location-specific cropping system models, mechanization, and market linkages, along with supportive policy interventions, will be crucial for scaling up millet-based systems. When integrated into diversified cropping systems through intercropping, crop rotation, mixed cropping, and agroforestry, millets contribute to enhanced system productivity, stability, and adaptability compared to conventional cereal-based monocropping systems. Their widespread adoption can play a significant role in ensuring sustainable food systems, conserving natural resources, and enhancing the adaptive capacity of agriculture in the face of climate change. These systems are increasingly recognized as a cornerstone for sustainable agriculture and food security in the context of climate change and shrinking natural resources (Ashoka et al., 2023; Bezbaruah & Singh, 2024).

References

1. Mishra, V., Yadav, N., Pandey, S., & Puranik, V. (2014). Bioactive components and nutritional evaluation of underutilized cereals. *Annals of Phytomedicine, 3*(1), 46–49.
2. Lithourgidis, A. S., Dordas, C. A., Damalas, C. A., & Vlachostergios, D. N. (2011). *Annual intercrops: An alternative pathway for sustainable agriculture*. *Australian Journal of Crop Science, 5*(4), 396–410.
3. Rai, K. N., et al. (2018). *Pearl millet breeding for climate resilience*. Journal of SAT Agricultural Research, 16, 1–10.
4. Gupta, S., Gupta, S. M., Gupta, A. K., Gaur, V. S., & Kumar, A. (2014). Fluctuation of Dof1/Dof2 expression ratio under the influence of varying nitrogen and light conditions: Involvement in differential regulation of nitrogen metabolism in two genotypes of finger millet (*Eleusine coracana* L.). *Gene, 546*(2), 327–335.
5. Tari, I., Laskay, G., Takács, Z., & Poór, P. (2013). Response of sorghum to abiotic stresses: A review. *Journal of Agronomy and Crop Science, 199*(4), 264–274.

6. Rai, K. N., Gowda, C. L. L., Reddy, B. V. S., & Sehgal, S. (2008). Adaptation and potential uses of sorghum and pearl millet in alternative and health foods. *Comprehensive Reviews in Food Science and Food Safety, 7*(4), 320–396.
7. Ashoka, P., Raut, D., Sudeepthi, B., Gawande, K. N., Reddy, G. S. V., Padhan, S. R., & Panigrahi, C. K. (2023). *Millet's role as a climate-resilient staple for future food security: A review*. *International Journal of Environment and Climate Change, 13*, 4542–4552.
8. Bezbaruah, R., & Singh, A. K. (2024). *Millets as nutricereal climate-resilient smart crops: A review*. *Journal of Experimental Agriculture International, 46*, 795–803.
9. Gupta, S. M., Arora, S., Mirza, N., Pande, A., Lata, C., Puranik, S., & Kumar, A. (2017). *Millets for climate-resilient agriculture*. *Indian Journal of Plant Physiology, 22*, 123–135.