



Editorial

Advancing Sustainable Development in Arid and Semi-Arid Agro-Ecosystems

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Arid and semi-arid regions are inherently shaped by water scarcity, climatic variability, land degradation, and fragile natural resources (Kaur *et al.*, 2025; Zaghoulani *et al.*, 2026; Das *et al.*, 2024). Yet, they also harbour remarkable biological diversity and offer substantial scope for agricultural innovation and sustainable resource management (Singh and Singh, 2025). This issue of *Annals of Arid Zone* brings together diverse contributions addressing these dryland challenges through research across soil and water management, climate change, crop and livestock production, biodiversity, agricultural economics, biological technologies, and resource conservation. Collectively, these studies illustrate how scientific understanding, technological innovation, and locally tailored interventions can combine to foster more productive and resilient dryland systems (Shekhawat, 2024).

Efficient management of soil, water, and biological resources emerges as a primary theme in this issue. Research on organo-mineral fertilizers highlights the potential of converting organic waste into valuable nutrient sources, simultaneously improving soil health and supporting circular-economy approaches. From a transfer-of-technology perspective, the Integrated Farming Cafeteria at ICAR-CAZRI provides a practical platform demonstrating crops, horticulture, fodder, livestock, and conservation technologies in an integrated setting; its engagement with over 5,800 farmers underscores the impact of experiential learning (Yadav, 2025). Addressing hydrological dynamics, investigations at Ouzert Dam identified distinct leakage regimes, emphasizing the necessity of long-term monitoring for dam seepage and regional groundwater safety.

Climate variability and land degradation are examined across both crop-specific and landscape scales. An analysis of cereal productivity across India's arid and semi-arid regions confirms that while temperature and aridity heavily dictate yields, agricultural inputs and financial factors exert an equally significant influence. Remote sensing and environmental tracking in North Africa highlight contrasting regional realities: in Algeria's El Bayadh, rising temperatures and deteriorating water balances persist despite localized

vegetation gains, whereas studies in Biskra reveal sharp vegetation declines driven by warming, irregular rainfall, and recurring drought. Similarly, a feature-space analysis of the Hodna Basin identified expansive zones under high to severe desertification threats. Together, these findings demonstrate that environmental change is spatially heterogeneous and demands site-specific diagnostic tools and solutions.

This issue also provides deep insights into ecological processes and biodiversity within drylands. A review of India's hot arid rangelands emphasizes the urgent need to conserve their unique flora and fauna while recognizing traditional conservation practices. Soil biology studies from the Brazilian Caatinga reveal that termite structures enhance localized soil fungal abundance, illustrating their functional role in belowground nutrient cycling. Furthermore, a comprehensive inventory of Libyan scorpions catalogues 28 species—including six endemics—while identifying key geographical gaps for future field research. Crucially, these contributions frame drylands not merely as resource-limited environments, but as biologically distinctive and dynamic ecosystems.

Crop improvement, stress tolerance, and bio-protection represent another strong focus. A chickpea study utilizing principal component analysis (PCA) and cluster analysis identifies genetically diverse, high-yielding genotypes valuable for future breeding programs. Fundamental research on adventitious root formation highlights physiological and molecular pathways key to plant establishment under abiotic stress. In crop protection, foliar application of salicylic acid significantly reduced *Cercospora* leaf spot in moth bean by stimulating biochemical defense mechanisms. Similarly, investigations into plant growth-promoting rhizobacteria (PGPR) and *Streptomyces* strains demonstrate promising avenues for biological disease suppression, growth enhancement, and salinity tolerance. Completing this thematic area, studies on fenugreek extracts, *Helianthus annuus* extracts, and date palm pollen showcase the untapped potential of plant-derived resources for agricultural, pharmaceutical, antioxidant, and reproductive applications.

Emerging pest threats and integrated management strategies receive targeted

coverage. Field trials using sucrose and fructose applications on potato crops revealed contrasting effects on the potato tuber moth, with a combined treatment successfully reducing infestation and larval density. Of immediate biosecurity concern is the first report of *Tuta absoluta* in the Jodhpur region, where severe infestations inflicted heavy losses on protected tomato crops. Early detection reports of this nature are vital for alerting regional stakeholders, strengthening field surveillance, and implementing timely management strategies in western Rajasthan.

Integrating crop production with livestock and extension services proves essential for sustainable rural livelihoods. Participatory crop-livestock interventions in Nagaur successfully boosted crop yields, fodder availability, milk production, and household income through combined improvements in agronomy, animal nutrition, and herd management. Conversely, a study in the Sojat goat-rearing belt found that while farmers widely adopt foundational health-care practices, constraints such as inadequate veterinary services, high treatment costs, physical distance, and limited technical knowledge continue to hinder progress. These findings highlight that technical recommendations must be paired with accessible extension networks and reliable service delivery.

The socioeconomic and institutional dimensions of dryland farming are thoroughly explored. An economic evaluation of extensive rainfed olive farming in Algeria demonstrated positive profitability, though returns remained sensitive to labor costs and productivity levels. In central Rajasthan, targeted government subsidies and capacity-building training accelerated the adoption of protected cultivation, expanding market opportunities despite barriers related to high initial capital investment.

Finally, field-level technology transfer demonstrates how research translates into practical gains. Results from Frontline Demonstrations in Pali recorded substantial yield advantages over traditional farmers' practices across green gram, cluster bean, sesame, wheat, mustard, and cumin. Importantly, technology gaps narrowed significantly through repeated technical exposure and

field supervision. Alongside the ICAR-CAZRI Cafeteria model, these field results reiterate that continuous farmer engagement is indispensable for transforming scientific innovations into real-world productivity and economic resilience.

Taken together, the contributions in this volume offer a holistic and coherent synthesis of modern arid-zone research—bridging molecular and microbial mechanisms, farm-level management, livestock systems, landscape dynamics, and socioeconomic realities. The common thread uniting these studies is the imperative to understand dryland systems within their specific ecological and human contexts. Advancing sustainable development in challenging agro-ecosystems requires solutions that are scientifically sound, economically viable, and adaptable to local conditions; the evidence presented in this issue marks a valuable step forward in that ongoing effort.

Ultimately, we hope this collection serves as a catalyst for future collaborative research and policy frameworks dedicated to securing a sustainable future for drylands worldwide.

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