AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 09 (September, 2026)
Available online at http://www.agrimagazine.in

Soil Health in Rainfed and Semi-Arid Dryland Agriculture: Building Resilience from the Ground Up

*Ashni Thomas
M.Sc. Scholar, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore – 641 003, Tamil Nadu, India
*Corresponding Author's email: ashnitpg@gmail.com

Rainfed and semi-arid drylands support nearly half of India's cultivated area, yet their soils are chronically low in organic carbon, nitrogen and micronutrients, and are highly vulnerable to erosion and moisture stress. This article examines why soil health is the foundation of productivity and resilience in these fragile ecosystems, outlines the major constraints farmers face, and discusses practical, field-proven management options — organic matter build-up, integrated nutrient management, conservation tillage, in-situ and ex-situ moisture conservation, crop diversification and agroforestry. Adopting an integrated soil health strategy can stabilise yields under erratic rainfall, cut input costs and slow land degradation, making dryland farming both more profitable and more climate-resilient.

Keywords: soil health, rainfed agriculture, semi-arid dryland, soil organic carbon, moisture conservation, integrated nutrient management

Introduction

Nearly 51% of India's net sown area is rainfed, contributing about 40% of the country's food grain production and supporting a large share of its livestock population. These lands lie mostly in the arid and semi-arid tropics, where rainfall is scanty, erratic and concentrated in a short monsoon window. Under such conditions, soil is not just a growing medium — it is the buffer that decides whether a crop survives a dry spell or fails outright. A healthy soil, rich in organic matter and with good structure, can store more water, release nutrients steadily and support stronger root systems that help crops withstand moisture stress. Unfortunately, decades of intensive cultivation, residue removal, minimal organic inputs and unchecked erosion have left many dryland soils depleted, setting the stage for a vicious cycle of low biomass, low organic return and further degradation.

Why Soil Health Matters More in Drylands

In irrigated systems, water can partly compensate for a tired soil; in rainfed systems, the soil itself must do the work of holding on to every drop of rain that falls. Soil organic carbon (SOC) is central to this capacity — it improves aggregate stability, water infiltration and the soil's water-holding capacity, while also feeding the microbial life that cycles nutrients. Research from India's semi-arid tropics has shown that even a modest rise in root-zone SOC stock can meaningfully reduce the yield penalty caused by short dry spells, and that soils receiving organic amendments lose less yield when rainfall is deficient. In other words, building soil organic matter is not a cosmetic improvement; it is a direct investment in drought resilience.

Key Constraints in Rainfed and Semi-Arid Soils

Several interlinked problems characterise dryland soils. Most are inherently low in organic carbon because high temperatures speed up decomposition while biomass production remains limited by moisture scarcity. Multi-location surveys across central India have reported

widespread deficiencies of sulphur, boron, zinc and phosphorus in farmers' fields, alongside low soil organic carbon in a large share of samples tested. Physical degradation is equally serious — compacted surface layers, poor infiltration, crusting and sheet or gully erosion are common where residues are removed for fodder or fuel and where land lies bare between crops. Continuous monocropping, driven by moisture constraints, further narrows nutrient cycling and offers little residue return. Together, these factors trap smallholder farmers in a cycle of declining fertility, shrinking yields and rising vulnerability to climate variability.

Building Soil Health: Practical Management Options

1. Organic matter build-up and integrated nutrient management

Combining organic sources — farmyard manure, compost, crop residues and green manures — with need-based mineral fertilisers under an integrated nutrient management (INM) approach has consistently improved soil quality indicators and yields in long-term dryland trials. Recycling crop residues rather than burning or removing them raises biologically active carbon and supports beneficial soil microbes, while also moderating soil temperature and conserving moisture. Biofertilizers such as phosphate-solubilising and nitrogen-fixing cultures further stretch the efficiency of costly mineral inputs.

2. Conservation tillage and residue management

Reduced or minimum tillage, combined with retaining at least 30% residue cover, cuts erosion losses and improves infiltration compared with clean cultivation. Trials on rainfed Alfisols have shown that minimum tillage with residue recycling improves biological soil health indicators while lowering surface carbon dioxide emissions, pointing to co-benefits for both productivity and climate mitigation.

3. In-situ and ex-situ moisture conservation

Because every millimetre of rainfall counts, moisture conservation is inseparable from soil health management in drylands. Contour bunding, graded bunds, ridge-and-furrow layouts, mulching and broad-bed-and-furrow systems slow runoff and increase infiltration, while farm ponds and check dams harvest excess monsoon flow for supplemental irrigation during dry spells. Watershed-based development, promoted widely by ICAR's Central Research Institute for Dryland Agriculture (CRIDA) and allied programmes, brings these practices together at a landscape scale, combining ridge-to-valley treatment with soil and nutrient management.

4. Crop diversification and agroforestry

Replacing continuous monocropping with intercropping, crop rotation involving legumes, and inclusion of drought-hardy millets improves nutrient cycling and adds diversity of root systems and residues. Agroforestry systems — integrating fast-growing trees, fodder grasses or horticultural species with field crops — add another layer of resilience, improving soil binding, organic matter addition and carbon sequestration while diversifying farm income and buffering against total crop failure in a bad monsoon year.

5. Site-specific and precision nutrient management

Since nutrient deficiencies vary sharply across dryland soils, blanket fertiliser recommendations often under- or over-supply specific nutrients. Soil testing-based, site-specific nutrient management — correcting secondary and micronutrient deficiencies such as sulphur, zinc and boron alongside major nutrients — has been shown to substantially raise both yield and profitability in semi-arid cropping systems, while reducing the risk of nutrient mining over time.

Conclusion

Soil health is the quiet foundation on which the productivity and stability of rainfed and semi-arid dryland agriculture rest. Because these systems cannot rely on irrigation to buffer poor soil condition, every unit of organic carbon added, every erosion event prevented and every drop of rainwater conserved translates directly into resilience against drought and yield variability. An integrated strategy — combining organic matter management, conservation tillage, moisture conservation, crop diversification and precision nutrient management — offers smallholder dryland farmers a realistic, low-cost pathway to healthier soils, steadier

yields and greater climate resilience. Extension systems and policy support must continue to make these science-backed, field-tested practices accessible to the millions of farmers who depend on the monsoon and their soil in equal measure.

Acknowledgement

The author gratefully acknowledges the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, for guidance and support.

References

1. Chander G, Wani SP, Sahrawat KL, Kamdi PJ, Pal CK, Pal DK, Mathur TP. 2013. Balanced and integrated nutrient management for enhanced and economic food production: case study from rainfed semi-arid tropics in India. *Arch. Agron. Soil Sci.* 59(12): 1643-1658.
2. Sharma KL, Gajbhiye PN, Mandal UK, Korwar GR, Grace JK, Madhavi M, Yadav SK, Srinivas K, Ramesh V, Usha Rani K. 2008. Effect of residue recycling on biological soil health indicators and surface CO2 emissions in rainfed semi-arid tropical Alfisol under minimum tillage conditions. *J. Agrometeorol.* 10 (Spl. Issue Part I): 46-50.
3. Srinivasarao Ch, Venkateswarlu B, Lal R, Singh AK, Kundu S. 2013. Sustainable management of soils of dryland ecosystems of India for enhancing agronomic productivity and sequestering carbon. *Adv. Agron*. 121: 253-329.
4. Indian Farming. 2025. Promising integrated farming systems for dryland agro-ecosystems. *Indian Farming* (ICAR).
5. ICAR-Central Research Institute for Dryland Agriculture (CRIDA). Rainfed farming research and watershed technologies. https://www.icar-crida.res.in. Accessed 21 August 2026.