



Productivity Constraints and Future Prospects of Rainfed Agriculture: A Comprehensive Review

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Rainfed agriculture is the backbone of food and livelihood security for a very large share of the world's farming population, particularly in the developing world. Unlike irrigated farming, rainfed cultivation depends entirely on natural precipitation to meet the water requirement of crops, which makes it inherently vulnerable to the vagaries of weather. Globally, close to 80 percent of the world's agricultural land is rainfed, and this land base supplies roughly 70 percent of staple food production, especially in regions where large-scale irrigation infrastructure has not developed (Current Agriculture Research Journal, n.d.). In India, dependence on rainfed farming remains substantial: recent estimates place the rainfed share of the net sown area anywhere between 46 and 58 percent depending on the year and definition used, spread across more than a hundred million hectares (Singh & Bhargavi, 2024; ScienceDirect, 2015; ISDA-RAINBURS, 2024). These tracts are also disproportionately important for the production of coarse cereals, pulses, oilseeds and cotton, crops that form the nutritional and economic base for millions of smallholder and marginal farmers. Despite this scale, productivity on rainfed land continues to lag far behind that of irrigated systems. Understanding why this gap persists, and what can realistically be done to close it, is essential not only for the welfare of dryland farmers but also for national and global food security in an era of intensifying climatic uncertainty.

Extent and Importance of Rainfed Agriculture

Rainfed regions are not marginal in an economic sense, even though the term "rainfed" is sometimes equated with backwardness. In India, these areas are estimated to contribute close to 60 percent of the country's agricultural gross domestic product and continue to support the livelihoods of a large share of the rural poor, even while facing weak soil health, high erosion, and limited moisture retention (Current Agriculture Research Journal, n.d.). Agriculture as a whole remains central to the Indian economy, supporting the livelihoods of roughly two-fifths of the population and contributing a substantial share of GDP, and the sector's overall performance is still heavily shaped by monsoon behaviour because so much cultivation remains rain-dependent (Global Agriculture, 2024). At the same time, per capita agricultural land availability in India has fallen well below that of developed countries, even as population and food demand keep rising, making productivity gains on existing rainfed land an urgent priority rather than an optional improvement (ResearchGate, 2015).

Productivity Constraints in Rainfed Agriculture

The persistently low and unstable productivity of rainfed farming is not the result of any single factor. Instead, it reflects the cumulative effect of climatic, soil-related (edaphic), technological and socio-economic constraints that interact with and reinforce one another (Walia, Kaur, & Kaur, 2024).

1. Climatic Constraints

Rainfall in dryland tracts is not just low in total quantity but highly erratic in its distribution. Annual rainfall can deviate by as much as 40 percent from long-term averages, and the timing, intensity and number of rainy days vary widely from year to year (Singh & Bhargavi, 2024). Long dry spells during critical crop growth stages, sudden high-intensity storms that cause runoff rather than infiltration, high potential evapotranspiration, and temperature extremes all combine to make yields unpredictable. In several regions, droughts and flash floods now occur within the same cropping season, a pattern that traditional cropping calendars were never designed to handle (ISDA-RAINBURS, 2024).

2. Edaphic (Soil-Related) Constraints

Rainfed soils are typically shallow, low in organic matter, and prone to erosion, which limits their capacity to store the moisture that does fall as rain. Soil degradation is estimated to affect 30 to 40 percent of agricultural land in dryland regions, while water scarcity affects a majority of the net sown area (Singh & Bhargavi, 2024). Nutrient deficiencies are widespread and severe: surveys report nitrogen deficiency in roughly 89 percent of rainfed soils, phosphorus deficiency in about 80 percent, and potassium deficiency in around half, along with widespread shortages of sulphur and micronutrients such as zinc, boron, iron and molybdenum (ResearchGate, 2015). Poor water- and nutrient-holding capacity, combined with low soil organic matter, leaves these soils inherently fragile and slow to recover once degraded (ISDA-RAINBURS, 2024).

3. Technological Constraints

Adoption of improved dryland technology remains uneven. Many farmers continue to rely on traditional, low-input crop varieties that were not bred for moisture-stress tolerance, and access to short-duration, drought-tolerant, or climate-resilient cultivars is still limited in several pockets. Mechanisation suited to small, fragmented dryland holdings is inadequate, and extension services often struggle to reach the more remote and resource-poor rainfed tracts with timely, location-specific advice. Water-harvesting structures, in-situ moisture conservation methods, and integrated nutrient and pest management practices, all of which are known to raise rainfed yields, are still not used at the scale needed.

4. Socio-Economic Constraints

Rainfed farming is dominated by small and marginal holdings, and land fragmentation further limits the scope for investment in water conservation or mechanisation. Roughly 30 percent of the rural population in dryland regions lives in poverty, and limited access to institutional credit, crop insurance and remunerative markets restricts farmers' ability to adopt new technology or absorb the risk of crop failure (Singh & Bhargavi, 2024). Because the returns from a single rainfed crop are often low and unstable, many households remain locked in subsistence-oriented farming rather than being able to diversify into higher-value, more resilient systems (Current Agriculture Research Journal, n.d.).

Future Prospects and Strategies for Improvement

None of these constraints are insurmountable. A growing body of research and field experience points to a set of strategies that, taken together, can meaningfully raise and stabilise rainfed productivity.

1. Watershed-Based and Soil-Water Conservation Approaches

Integrated watershed management, in-situ moisture conservation, contour bunding and community-level water harvesting have repeatedly been shown to stabilise yields by capturing rainfall where it falls and reducing runoff losses. Rainwater harvesting systems, for instance, have helped raise crop yields and resilience during dry seasons in dryland regions of Ethiopia and elsewhere, showing that even modest infrastructure investment can meaningfully cushion the effect of erratic rainfall (FAO, 2025).

2. Climate-Resilient and Drought-Tolerant Varieties

Plant breeding, both conventional and biotechnology-assisted, continues to expand the pool of varieties that can maintain yield under water-limited conditions. Breeding programmes are increasingly combining genomic tools with physiological insight to develop cultivars with

improved water-use efficiency and stress tolerance, while sustaining or even improving yield potential at the same time (Oxford Academic, 2023). In staple crops such as maize, long-term breeding trials have shown that yield gains and improved drought resistance can be achieved together rather than as a trade-off (PMC, 2025). Flood-tolerant rice varieties are similarly improving resilience in rainfed lowland systems that face both drought and waterlogging risk within the same season (bioRxiv, 2024).

3. Conservation Agriculture and Diversified Cropping

Minimum tillage, cover cropping, crop rotation and diversified cropping patterns help build soil organic matter, improve infiltration, and reduce erosion, while also spreading risk across crops rather than concentrating it in a single rainfed cereal (FAO, 2025). Integrated farming systems that combine crops with livestock, horticulture or dairy have been shown in multiple Indian states to generate substantially higher net returns and more stable incomes than cropping alone, in some cases two to seven times higher than conventional cropping systems (Singh & Bhargavi, 2024).

4. Precision Tools, Early Warning and Digital Advisory

Satellite-based early warning tools, such as the FAO Agricultural Stress Index System, allow drought conditions and crop stress to be identified early enough for corrective action, while AI-assisted sensors, drones and smart irrigation scheduling are beginning to help farmers use scarce soil moisture more efficiently (FAO, 2025; PMC, 2025). Machine-learning-based climate models are also being used by breeders to anticipate future stress patterns and design varieties suited to the climate conditions expected decades from now rather than only current conditions (PMC, 2025).

5. Strengthening Institutional and Policy Support

Wider access to credit, crop insurance, remunerative output prices, and location-specific extension advice would allow more rainfed farmers to adopt available technology and absorb short-term risk. Government-supported dryland development programmes, running in India since the Fourth Five-Year Plan, illustrate that sustained policy attention to rainfed regions can shift outcomes over time, though experience also shows that such interventions need to be designed so that gains reach small and marginal farmers rather than only those who can afford complementary investments such as groundwater extraction (Current Agriculture Research Journal, n.d.; Academic Strive, n.d.).

Conclusion

Rainfed agriculture will remain central to food security, rural livelihoods and ecological balance across large parts of the world for the foreseeable future. Its productivity constraints are real and interconnected, spanning climate, soil, technology and socio-economic circumstance, but they are also well understood and, in many cases, already being addressed successfully in pockets of good practice. The path forward lies not in any single silver-bullet technology but in combining improved soil and water management, climate-resilient varieties, diversified and integrated farming systems, precision advisory tools, and stronger institutional support in a way that reaches the small and marginal farmers who cultivate most of this land. Investment made today in strengthening the resilience of rainfed systems will directly determine how well global agriculture can withstand the climatic uncertainty of coming decades.

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