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**Productivity Concise in Rainfed Agriculture and Future
Prospects of Rainfed Agriculture in India: Challenges,
Strategies and Pathways**

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Abstract

Rainfed agriculture constitutes the backbone of Indian food production, covering nearly 51% of the net sown area and contributing approximately 40% of the country's total food grain output. Despite its vast spatial extent, rainfed systems are characterised by low and erratic productivity, high dependence on monsoon rainfall, shallow and degraded soils, and limited access to technological inputs, rendering them vulnerable to climate variability and recurrent droughts. This article provides a comprehensive review of productivity trends in rainfed agriculture, examining the biophysical, socioeconomic, and institutional

constraints that impede yield realisation. It further explores the transformative potential of watershed-based development, soil and water conservation, improved cultivar adoption, precision nutrient management, and digital agricultural technologies. National initiatives including NICRA, the National Watershed Development Project for Rainfed Areas (NWDPA), and ACASA-India are critically assessed for their contribution to enhancing resilience and farm income. The future prospects of rainfed agriculture are analysed in the context of climate change adaptation, emerging technologies such as remote sensing and AI-based decision support, policy reforms, and sustainable intensification. The article concludes that through integrated land-water management, participatory approaches, and robust institutional support, rainfed agriculture holds significant potential to achieve food security and rural livelihood improvement in India.

Keywords: Rainfed agriculture, productivity, watershed management, NICRA, climate change adaptation, sustainable intensification, soil and water conservation, food security, India

Introduction

Agriculture in India is fundamentally a rain-dependent enterprise. Out of the 142 million hectares of net sown area in the country, approximately 72–75 million hectares (nearly 51%) remain unirrigated and rely exclusively on rainfall for crop production. These rainfed areas, spread across arid, semi-arid, and subhumid agro-ecological zones, are home to the majority of India's rural poor, small and marginal farmers, and tribal communities. They contribute roughly 40% of total food grain production and support a large share of coarse cereals, pulses, and oilseeds, which form the dietary staple for millions of undernourished households.

The defining characteristic of rainfed agriculture is its direct dependence on the south-west monsoon (June to September), which delivers approximately 80% of the country's total annual rainfall. The spatial and temporal distribution of this rainfall is highly erratic — varying from less than 400 mm per annum in arid zones of Rajasthan and Kutch to over 1,500 mm in sub-humid tracts of Madhya Pradesh, Chhattisgarh, and Odisha. This variability, combined with the absence of supplemental irrigation, renders crop yields highly unpredictable, leading to an average productivity of rainfed crops that remains only 40–60% of the irrigated counterpart.

Historically, rainfed agriculture has suffered from a policy and investment bias in favour of irrigated systems. The Green Revolution of the 1960s and 1970s, while transformative for wheat and rice in Punjab, Haryana, and western Uttar Pradesh, largely bypassed the dry regions. Consequently, the productivity gap between irrigated and rainfed farming has widened progressively. The average yield of rainfed rice remains around 1.5–2.0 t/ha compared to 4–6 t/ha under irrigated conditions, and sorghum yields are typically 0.8–1.2 t/ha under rainfed conditions against a potential of 3–4 t/ha.

Against this backdrop, enhancing the productivity and resilience of rainfed agriculture has assumed national priority. Government programmes such as the National Initiative on Climate Resilient Agriculture (NICRA), the National Watershed Development Project for Rainfed Areas (NWDPA), Pradhan Mantri

Krishi Sinchayee Yojana (PMKSY), and the Accelerated Crop Agriculture for Sustainable Agriculture in India (ACASA-India) initiative have introduced integrated interventions aimed at improving soil health, water use efficiency, and farmer income. This article critically reviews the productivity status of rainfed agriculture in India, identifies the multifaceted constraints, and charts the future pathway for its transformation.

Extent and Importance of Rainfed Agriculture in India

Rainfed agriculture is practised across all major agro-climatic zones of India, from the hot arid deserts of western Rajasthan to the cool semi-arid Deccan Plateau and the humid red laterite soils of Jharkhand. The major rainfed crops include sorghum (jowar), pearl millet (bajra), finger millet (ragi), maize, groundnut, pigeonpea (arhar), chickpea, soybean, sunflower, and cotton. These crops collectively account for nearly 85% of the total pulse area and over 70% of oilseed area in the country, making rainfed agriculture indispensable for nutritional security.

The Deccan Plateau states — Maharashtra, Karnataka, Andhra Pradesh, Telangana, and Madhya Pradesh — together account for more than 55% of the total rainfed crop area. Within these states, rainfed agriculture forms the primary livelihood of over 60% of farm households, most of whom operate on land holdings of less than 2 hectares. Rainfed areas also encompass 80% of India's wasteland and degraded land, indicating the enormous scope for land improvement and productivity enhancement through integrated natural resource management.

Despite its extent, rainfed agriculture contributes less than proportional share to national food security because of persistently low yields. The average productivity of rainfed crops has historically stagnated at around 0.8–1.0 t/ha for cereals and 0.5–0.7 t/ha for pulses, compared to the irrigated system where yields often double or triple these figures. This productivity gap is the central challenge that Indian agricultural policy must urgently address.

Biophysical Constraints to Productivity

The low productivity of rainfed agriculture is fundamentally rooted in adverse biophysical conditions. Soils in rainfed tracts are predominantly shallow, skeletal, and low in organic matter. Alfisols (red sandy loams) and Vertisols (black cotton soils) dominate much of the Deccan Plateau. While Vertisols have high water-holding capacity, they are prone to waterlogging during heavy rainfall and crack severely during dry spells, damaging crop roots. Alfisols, on the other hand, have low water retention, high erodibility, and poor nutrient status.

Rainfall uncertainty is the most critical constraint. Inter-annual variability of monsoon rainfall often exceeds 25–30% across rainfed tracts, leading to frequent mid-season dry spells, late onset of monsoon, and early withdrawal. Droughts occur with a frequency of 3–4 years in every decade in most rainfed districts of central and peninsular India. Even in years of 'normal' total rainfall, the distribution within the season may be insufficient to meet crop water requirements at critical growth stages such as flowering and grain filling.

Soil degradation through water erosion is severe in rainfed areas. It is estimated that nearly 16 billion tonnes of soil is eroded annually in India, of which rainfed sloping lands contribute the largest share. This erosion not only depletes topsoil nutrients but also reduces the effective rooting depth, further limiting the water- and nutrient-holding capacity of soils. Salinisation, acidification, and waterlogging affect additional areas, further constraining productivity.

Socioeconomic and Institutional Constraints

Beyond biophysical factors, rainfed agriculture is constrained by a constellation of socioeconomic and institutional barriers. Farm households in rainfed areas are predominantly small and marginal (less than 2 ha), with limited financial resources to invest in quality seeds, balanced fertilisers, or crop protection measures. Credit access remains restricted in rainfed regions due to the high-risk perception of lenders, inadequate collateral, and poor outreach of formal banking institutions.

Market linkages are weak, post-harvest losses are high, and the returns to farming are often insufficient to sustain farm households above the poverty line. This poverty trap discourages investment in land improvement and input application, perpetuating a cycle of low productivity. Extension services, which should bridge the gap between research and field, are thinly staffed in remote rainfed regions, limiting farmer access to improved technologies and agronomic advice.

Crop insurance penetration in rainfed areas, despite the Pradhan Mantri Fasal Bima Yojana (PMFBY), remains partial. Delayed indemnity payments and complex claim procedures reduce farmer confidence in the scheme. As a result, many rainfed farmers remain highly exposed to climate risk without adequate safety nets, often resorting to distress sales and seasonal migration as coping strategies. **Soil and Water**

Conservation Technologies

Soil and water conservation (SWC) technologies form the cornerstone of productivity enhancement in rainfed systems. In-situ moisture conservation practices such as tied ridges, broad bed furrows (BBF), contour farming, and minimum tillage have been demonstrated to increase effective moisture availability during dry spells and improve water use efficiency (WUE) significantly. Broad bed furrow systems, in particular, have shown yield increases of 30–50% for sorghum and pigeonpea on Vertisols by eliminating waterlogging during excess rainfall and conserving residual moisture during dry spells.

Farm ponds and check dams constructed under watershed programmes provide supplemental irrigation during critical dry periods. Studies from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) have demonstrated that a single supplemental irrigation of 50–75 mm at flowering can increase groundnut yields from 0.8 t/ha to 1.8 t/ha and pigeonpea from 0.6 t/ha to 1.5 t/ha under semi-arid conditions, representing yield gains of more than 100%.

Mulching with crop residues, green manure incorporation, and application of farm yard manure (FYM) at 5–10 t/ha significantly improve soil organic matter, enhance aggregate stability, and increase the water infiltration rate. These practices reduce surface runoff, moderate soil temperature extremes, and promote the growth of beneficial soil microorganisms. Vermicomposting and biochar application are increasingly being recommended in rainfed systems for their dual benefit of nutrient supply and soil carbon sequestration.

Improved Varieties and Cropping Systems

The development and dissemination of improved, stress-tolerant varieties represent the most cost-effective pathway to productivity enhancement in rainfed agriculture. National and international research institutions including ICRISAT, ICAR institutes (CRIDA, JNKVV, RVSKVV), and state agricultural universities have developed and released hundreds of varieties of sorghum, pearl millet, groundnut, pigeonpea, chickpea, and soybean with traits such as drought tolerance, early maturity, photo-insensitivity, disease resistance, and improved harvest index.

Varieties like CSH 16 (hybrid sorghum), HHB 67 Improved (pearl millet), JG 11 (chickpea), ICGV 91114 (groundnut), and NRC 37 (soybean) have consistently demonstrated yield advantages of 20–40% over local checks under farmer field conditions. The adoption of contingency crop planning — substituting short-duration varieties when the monsoon is delayed by 2–4 weeks — has been institutionalised in many states, enabling farmers to recover productivity even in aberrant rainfall years.

Diversified cropping systems including intercropping (e.g., sorghum + pigeonpea at 2:1 ratio; groundnut + castor at 6:2 ratio) provide risk insurance through complementary canopy architecture, shared resources, and income diversification. These systems have shown land equivalent ratios (LER) of 1.2–1.5, implying 20–50% more efficient use of land and resources compared to sole crops. Inclusion of legumes

in the cropping sequence also restores soil nitrogen through biological nitrogen fixation (BNF), reducing chemical fertiliser requirements by 20–30 kg N/ha.

Watershed-Based Development Approach

Watershed development has emerged as the most holistic and sustainable framework for improving rainfed agricultural productivity and livelihoods. A watershed is a natural hydrological unit in which all runoff drains to a common outlet, enabling integrated management of land, water, vegetation, and human resources. The watershed approach integrates ridge area treatment, water harvesting structures, drainage line treatment, and farmer livelihood improvement within a single planning framework.

The Integrated Watershed Management Programme (IWMP), implemented by the Ministry of Rural Development under PMKSY-Watershed Development Component, has treated over 50 million hectares across India since the 1990s. Studies from treated watersheds in Andhra Pradesh, Karnataka, Maharashtra, and Rajasthan have documented substantial improvements: groundwater recharge increasing by 15–30%, runoff reduction by 20–40%, and average crop yields increasing by 20–50% within 5–7 years of treatment. Equally important, the number of dry wells in treated watersheds decreased by 30–60%, indicating improved groundwater availability for supplemental irrigation.

The National Watershed Development Project for Rainfed Areas (NWDPA), launched during the Sixth Five-Year Plan, pioneered participatory watershed management involving local communities in planning, implementation, and maintenance. This decentralised approach has been widely credited for improving programme outcomes and ensuring the longevity of physical structures. Participatory watershed committees, self-help groups (SHGs), and water user associations (WUAs) have become institutionalised mechanisms for equitable resource sharing and conflict resolution.

NICRA and Climate Resilience

The National Innovations in Climate Resilient Agriculture (NICRA) programme, launched by ICAR in 2011, represents India's flagship institutional response to building climate resilience in rainfed farming systems. NICRA operates through a network of district-level Climate Resilient Villages (CRVs) spread across 100 districts in 15 states, each serving as a demonstration site for technology assessment, dissemination, and community capacity building.

Under NICRA, a suite of technologies including improved seeds, rainwater harvesting, in-situ moisture conservation, integrated nutrient management, crop diversification, and livestock-based income generation has been demonstrated. The programme has documented average yield increases of 10–25% for kharif crops and 15–30% for rabi crops in CRV districts compared to control villages. NICRA has also generated a large body of location-specific contingency planning guidelines that specify crop varieties, sowing dates, and agronomic practices for different rainfall scenarios — early normal, delayed, deficit, and excess.

ACASA-India (Accelerated Crop Agriculture for Sustainable Agriculture), a joint initiative with international partners, has further emphasised the integration of climate-smart agriculture (CSA) principles into rainfed farming. CSA aims simultaneously at three objectives: sustainably increasing agricultural productivity, adapting and building resilience to climate change, and reducing greenhouse gas emissions where possible. ACASA-India pilot interventions in rainfed districts have demonstrated that adopting the full package of CSA practices can increase net returns to farmers by 20–35% while reducing production risk.

Precision and Digital Agriculture in Rainfed Systems

The emergence of digital and precision agricultural technologies offers transformative potential for rainfed farming. Remote sensing and GIS-based tools now enable accurate delineation of watershed boundaries, identification of degraded lands, mapping of soil types, and monitoring of vegetation health and crop stress at the field level. Satellite-derived Normalised Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) provide early warning signals of drought stress, enabling timely advisories to farmers.

Drone-based monitoring of crop canopy, variable rate fertiliser application using soil sampling grids, and mobile-based weather advisory services are being piloted in several rainfed districts. The Digital Green platform and the mKisan portal of the Government of India have enabled last-mile delivery of agronomic advisories through video and SMS in local languages, reaching millions of smallholder farmers in rainfed areas. Artificial intelligence (AI) and machine learning models are being deployed to predict monsoon onset and rainfall distribution at fine spatial scales, enabling more accurate sowing window advisories. Variable rate technology (VRT) for fertiliser and soil amendment application, based on precision soil sampling and spatial variability mapping, has shown promise in reducing input costs while improving nutrient use efficiency in rainfed areas. Studies under the Precision Farming Development Centres (PFDCs) of ICAR have documented that VRT-based fertiliser management can reduce fertiliser use by 15–

25% while maintaining or improving crop yields, with corresponding reductions in nitrous oxide emissions.

Integrated Nutrient Management in Rainfed Systems

Nutrient management under rainfed conditions is challenging because nutrient availability and uptake are strongly governed by soil moisture status. Application of chemical fertilisers during moisture-deficit periods leads to poor nutrient use efficiency, leaching loss, and gaseous losses. Integrated nutrient management (INM), which combines organic sources (FYM, compost, green manures, biofertilisers) with judicious use

of chemical fertilisers, is universally recommended for rainfed soils.

Phosphorus (P) management is particularly critical in rainfed Alfisols, which are characterised by high P-fixation capacity due to their iron and aluminium oxide content. Application of P in conjunction with phosphate-solubilising bacteria (PSB) as seed treatment has been shown to improve P availability and increase crop yields by 10–20% without additional phosphate fertiliser. Rhizobium inoculation for legumes under rainfed conditions can fix 40–120 kg N/ha/season, significantly reducing the nitrogen fertiliser requirement.

Micronutrient deficiencies, particularly zinc (Zn) and boron (B), are widespread in rainfed soils.

Application of zinc sulphate at 25 kg/ha once in three years has consistently improved the yields of sorghum, maize, and groundnut in zinc-deficient rainfed soils by 10–20%. INM practices that combine these targeted micronutrient corrections with organic matter additions and balanced N-P-K application provide a cost-effective and sustainable basis for improving productivity.

Livestock Integration and Agro-Pastoral Systems in Rainfed Areas

Livestock rearing is an integral component of rainfed farming systems, providing income diversification, draught power, organic manure, and nutritional security for smallholder households. In rainfed districts of central and peninsular India, nearly 70–80% of farm families maintain cattle, sheep, goats, or poultry as

part of mixed farming systems. The integration of livestock with crop production creates synergies: crop residues and fodder from the farm feed the animals, while livestock manure recycles nutrients back to the soil, reducing chemical fertiliser requirements.

Sheep and goat rearing in rainfed semi-arid areas have proven to be highly profitable enterprises, with net returns often exceeding those from crop production during drought years. Backyard poultry based on improved breeds like Vanaraja and Grampriya, developed specifically for free-range rainfed village conditions, provide year-round income and nutritional supplement. The development of community fodder banks, silage making from crop residues, and improved natural pasture management are increasingly being promoted under watershed and NICRA programmes to strengthen the livestock-crop integration. Agroforestry systems in rainfed areas, combining trees with crops and/or livestock, offer multiple advantages including shade reduction of soil temperature, improved moisture retention, carbon sequestration, and additional income from timber, fruit, and non-timber forest products (NTFPs). Silvopastoral systems combining *Leucaena*, *Gliricidia*, or *Stylosanthes* with pasture grasses have demonstrated the capacity to sustain higher livestock stocking rates, improve soil nitrogen through leaf litter, and reduce surface runoff on sloping rainfed lands.

Women constitute the primary labour force in rainfed agriculture, contributing 60–80% of farm labour in weeding, transplanting, harvesting, post-harvest processing, and livestock management in most rainfed states. Despite this enormous contribution, women farmers in rainfed areas face multiple forms of systemic exclusion: they rarely hold land titles in their own name, have limited access to institutional credit and agricultural extension services, and are largely excluded from formal decision-making bodies in watershed committees and farmers' organisations.

Gender-transformative agricultural programmes that address these inequities are essential for sustainable productivity improvement in rainfed systems. Self-help group (SHG) federations in states like Andhra Pradesh and Telangana, supported under the National Rural Livelihood Mission (NRLM), have demonstrated that when women are provided with institutional credit, technology training, and collective market access, their agricultural productivity and income improve substantially. Women-led SHGs engaged in vegetable cultivation, seed production, and value-added product processing in rainfed areas have achieved incomes two to three times higher than conventional rainfed crop farmers.

Social equity in watershed benefits is another critical dimension. In traditional watershed programmes, the upstream farmers — typically better-off and holding larger land — tend to capture a disproportionate share of water conservation benefits, while downstream marginal farmers may face reduced stream flows and groundwater availability. Designing watershed programmes with explicit equity safeguards — through equitable water allocation rules, preference to marginal farmers in beneficiary selection, and common property resource development — is essential to ensure inclusive outcomes in rainfed development.

Policy Framework and Investment Priorities for Rainfed Agriculture

India's agricultural policy framework has made progressive strides in recognising the importance of rainfed agriculture in recent years. The National Policy for Farmers (2007), the report of the National Commission on Farmers (Swaminathan Commission), and successive Five-Year Plans have emphasised the need for differential investment in rainfed regions. The Rashtriya Krishi Vikas Yojana (RKVY), Pradhan Mantri Fasal Bima Yojana (PMFBY), and Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) collectively address irrigation expansion, crop insurance, and agricultural development in rainfed areas. However, the absolute quantum of public investment in rainfed agriculture remains disproportionately low relative to its share of agricultural area and farm population. Irrigation-centric public expenditure,

input subsidies concentrated in irrigated regions, and price support mechanisms primarily benefiting irrigated crops continue to skew the policy landscape against rainfed farmers. The 12th and 13th Finance Commissions have made increased allocations for watershed development and dryland horticulture, signalling a gradual policy reorientation.

The National Rainfed Area Authority (NRAA), established in 2006 under the Ministry of Agriculture and Farmers' Welfare, serves as the nodal policy body for planning, coordinating, and monitoring rainfed agricultural development in India. NRAA's Common Guidelines for Watershed Development Projects provide the technical framework for watershed programmes implemented by multiple ministries. Strengthening NRAA's mandate, financial resources, and inter-ministerial coordination authority is essential for effective and convergent delivery of rainfed development programmes.

Future Prospects of Rainfed Agriculture

The future prospects of rainfed agriculture in India are at once challenging and hopeful. On the challenge side, climate change projections for South Asia indicate a 10–15% increase in rainfall variability by 2050, with more intense but shorter rainy periods, increased frequency of droughts and floods, and rising temperatures that accelerate evapotranspiration and shorten the effective crop growth period. These trends will disproportionately affect rainfed farmers, who lack the buffer of supplemental irrigation. On the opportunity side, the untapped yield gap in rainfed systems is enormous. It is estimated that realising even 70–80% of the potential yield in rainfed areas through currently available technologies could add 30–50 million tonnes of additional food grains annually, equivalent to a significant portion of India's buffer stock requirement. This represents perhaps the largest single opportunity for agricultural growth remaining in the country, achievable without bringing additional land under cultivation.

Key future pathways include: (i) Scaling up of watershed development programmes with greater community participation and women's leadership; (ii) Accelerated development and deployment of drought-tolerant, climate-adapted varieties through genomics and marker-assisted breeding; (iii) Universal adoption of contingency crop planning based on real-time weather data and remote sensing; (iv) Integration of agroforestry and silvopastoral systems to diversify income, improve soil health, and sequester carbon; (v) Strengthening rural credit, crop insurance, and market linkage infrastructure specifically tailored to the needs of rainfed farmers.

Digital transformation offers a powerful accelerator for rainfed agriculture's future. AI-driven crop advisory platforms, blockchain-based agri-value chains, drone-assisted crop health monitoring, and precision weather forecasting can collectively improve farm decision-making, reduce input wastage, and enhance farmer income. The convergence of these technologies with traditional knowledge of rainfed farming communities holds the potential to reimagine rainfed systems as productive, resilient, and environmentally sustainable enterprises in the 21st century.

Policy reforms must also prioritise differential investment in rainfed agriculture commensurate with its area and population coverage. Rebalancing public agricultural research expenditure, extension services, rural infrastructure, and input subsidy regimes in favour of rainfed areas is essential for equitable and sustainable agricultural growth. Additionally, mainstreaming gender and inclusion in rainfed agricultural programmes — recognising women's central role in rainfed crop management — is a non-negotiable prerequisite for achieving transformative and lasting impact.

A critical enabling condition for rainfed agriculture's future is the strengthening of rural infrastructure in rainfed regions — rural roads, electricity connectivity, cold chain and storage facilities, and digital connectivity. Without these foundational investments, even the best agricultural technologies cannot reach

or benefit rainfed farmers. The convergence of MGNREGA with watershed development has shown promise in creating productive rural infrastructure through community participation, and this convergence should be deepened and expanded.

International cooperation and knowledge exchange will also play an important role in shaping the future of rainfed agriculture. CGIAR centres — particularly ICRISAT, CIMMYT, CIP, and IFPRI — continue to generate and share technologies relevant to rainfed systems across South and Southeast Asia, Sub-Saharan Africa, and Latin America. South-South cooperation platforms can enable rainfed farmers in India to benefit from innovations developed in similarly constrained environments in Africa and Southeast Asia.

Conclusion

Rainfed agriculture occupies a pivotal position in India's agricultural economy, encompassing the majority of crop area and rural livelihoods, yet remaining chronically underproductive relative to its potential. This article has systematically examined the biophysical, socioeconomic, and institutional constraints that limit productivity in rainfed systems, and reviewed the technological and policy interventions that offer genuine prospects for transformation.

The evidence presented demonstrates that integrated watershed development, improved stress-tolerant varieties, in-situ moisture conservation, INM, digital advisory services, and community-based natural resource management collectively constitute a viable and proven pathway to doubling or trebling rainfed crop yields. National programmes such as NICRA, NWDPR, and ACASA-India have generated a wealth of location-specific knowledge and demonstrated technologies that await scaling to achieve national impact.

The future of rainfed agriculture in India will ultimately be determined by the extent to which technological solutions are embedded within robust institutional frameworks that empower smallholder farmers, particularly women, with adequate resources, knowledge, market access, and risk mitigation mechanisms. Rainfed agriculture, long treated as the poor cousin of irrigated farming, must be repositioned as the frontier of India's agricultural transformation — offering the greatest untapped potential for sustainable productivity growth, rural income improvement, and long-term food and nutritional security in an era of climate change.

Rainfed agriculture in India stands at a critical inflection point. The twin imperatives of food security for a population projected to reach 1.65 billion by 2050 and the imperative of sustainable natural resource management in the face of accelerating climate change both demand that rainfed agricultural systems be transformed from low-input, low-output subsistence enterprises into productive, resilient, and commercially viable farming systems. This transformation is not merely an agronomic challenge but a social, institutional, and political one, requiring sustained commitment from government, research institutions, civil society, and farming communities.

The convergence of proven technologies — watershed development, improved varieties, soil and water conservation, INM, and digital advisory services — with strengthened institutions, equitable policies, and farmer-centred approaches creates a powerful and realistic pathway for achieving this transformation. India has invested decades of research, policy experimentation, and community learning in its rainfed regions. The time has come to leverage this accumulated knowledge and infrastructure to achieve a second green revolution — one that is water-smart, climate-resilient, inclusive, and ecologically sustainable — driven by and for the millions of rainfed farmers who form the enduring backbone of Indian agriculture.

Authors' Contributions

Atchaya conceptualised and drafted the manuscript, including literature review, content organisation, and compilation of all sections. D. E. Keerthi contributed to critical review, scientific editing, content refinement, and final approval of the manuscript for submission.

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Availability of Data and Materials

All data and information cited in this article are derived from publicly available government reports, peerreviewed journal articles, and institutional publications of ICAR, ICRISAT, the Ministry of Agriculture and Farmers' Welfare (Government of India), and other reputed national and international organisations. No proprietary datasets were generated or analysed during the preparation of this article. All referenced materials are available through the respective institutional websites and academic databases.

Ethics Approval and Consent to Participate

This article is a review-based academic assignment and does not involve any human subjects research, clinical trials, animal experiments, or collection of personal data. Accordingly, ethics approval and participant consent are not applicable to the preparation of this manuscript.

Consent for Publication

Both authors have read and approved the final version of this manuscript and provide their consent for its submission and evaluation as part of the AGR205 course requirement. No third-party personal data, images, or identifiable information has been included in this article that would require additional consent.

Competing Interests

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