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When the Rains Falter: How Dryland Farmers Can Beat the El Niño Challenge

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INTRODUCTION

Rainfed agriculture is highly sensitive to timing, amount and distribution of rainfall. Delayed onset of monsoon can postpone sowing and shorten the growing period, while prolonged dry spells can impair germination, establishment, growth and yield of crops. Water deficits during flowering, pod development and grain filling can cause substantial yield losses, particularly where irrigation and alternative livelihood options are limited. El Niño, the warm phase of ENSO, involves anomalous warming of the central and eastern equatorial Pacific and associated atmospheric circulation changes that can influence rainfall remotely. However, its impact varies spatially and seasonally and does not provide a deterministic drought prediction. El Niño should therefore be treated as a climate-risk signal supporting preparedness. Climate-resilient farming depends on combining timely information with sound agronomic practice. Climate forecasts, field observations, soil moisture status and farmers' local knowledge should together guide decisions on crop selection, water conservation, soil health, efficient irrigation and diversified cropping systems.

2. El Niño and Climate Variability

ENSO represents an important source of year-to-year climate variability and influences atmospheric circulation at regional and global scales. During El Niño conditions, anomalous tropical Pacific warming modifies atmospheric pressure gradients, convection and circulation, thereby affecting precipitation patterns in remote regions. The Indian summer monsoon exhibits a significant but non-linear association with ENSO and historical observations indicate that El Niño conditions are often associated with an increased probability of below normal monsoon rainfall (Athira *et al*., 2023). However, this relationship is not deterministic. Other climatic processes, including the Indian Ocean Dipole and intraseasonal atmospheric variability, can strengthen, weaken or modify the ENSO-monsoon relationship.

Consequently, some El Niño years may receive adequate or near-normal monsoon rainfall, while deficient rainfall can also occur under neutral or La Niña conditions. Agricultural decisions should therefore treat ENSO information as one input within a broader climate-risk assessment, alongside seasonal rainfall outlooks, recent precipitation, soil-moisture status, crop condition and location-specific advisories.

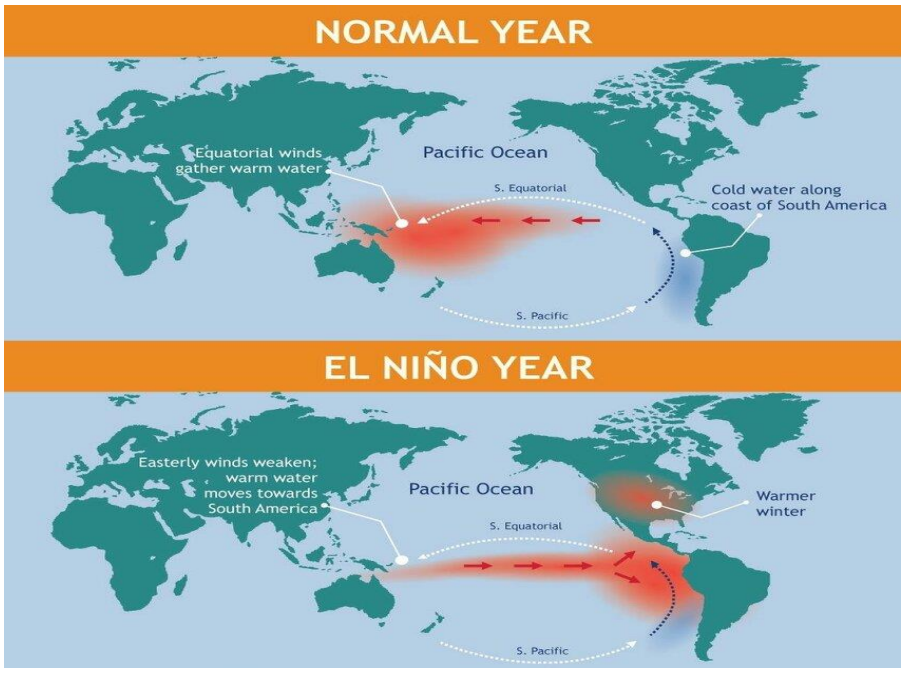


Fig. 1: El Niño and its effect in India

3. Rainfall Variability and Crop Water Stress

Soil moisture is the critical link between rainfall and crop productivity, determining how much water is actually available to plants. When evapotranspiration exceeds the replenishment of soil water, plants experience progressive water stress. Physiological responses include stomatal closure, reduced carbon assimilation, restricted leaf expansion and changes in root and shoot development (Wang *et al*., 2024). Prolonged stress can accelerate senescence and disrupt reproductive processes, ultimately reducing yield.

The consequences of water stress depend strongly on its timing. Deficits during flowering, pollination, pod formation and grain filling are generally more detrimental than equivalent stress during relatively tolerant developmental stages (Wang *et al*., 2024). Furthermore, intense rainfall can exceed soil infiltration capacity, cause runoff and erosion while contributing relatively little to root-zone water storage. Therefore, the temporal pattern and effectiveness of rainfall may be more important for crop performance than seasonal rainfall totals alone. Increasing infiltration, reducing runoff and conserving soil water are thus fundamental components of dryland farming.

4. Vulnerability of Small and Marginal Farmers

Rainfall variability affects not only agricultural productivity but also the socioeconomic stability and livelihood security of smallholder farming households. Limited access to irrigation facilities, institutional credit, quality inputs, modern technologies and adequate land resources often constrains their capacity to withstand and recover from climate-related shocks. Crop failure can lead to substantial losses in household income and food availability, while reducing savings and

limiting investment in agricultural inputs and farm operations for subsequent cropping seasons. Consequently, recurrent rainfall fluctuations can reinforce the cycle of agricultural vulnerability, economic insecurity and declining resilience among smallholder farmers.

Livestock plays a vital role in sustaining dryland livelihoods by providing milk, meat, manure and supplementary income, thereby diversifying household income sources and reducing dependence on crop production. However, drought conditions can diminish the availability of green fodder, crop residues and drinking water thereby increasing livestock maintenance costs and adversely affecting animal health and productivity. These challenges highlight the need for climate-risk management strategies that address crop and livestock enterprises in an integrated manner. Furthermore, farm resilience should not be assessed solely in terms of avoiding production losses; rather, it encompasses the capacity of farming systems to minimize the severity of losses, maintain essential production and livelihood functions during climatic disturbances and recover efficiently once favourable conditions return.

5. Crop and Variety Selection

Selection of suitable crops and cultivars is a fundamental adaptation strategy for managing uncertain rainfall. Crops and varieties differ significantly in growth duration, rooting characteristics, water requirements and tolerance to moisture stress. Under suitable agroecological conditions, millets, sorghum, pulses and selected oilseed crops can contribute to diversified and relatively water-efficient dryland production systems.

Short-duration cultivars are particularly valuable when the monsoon is delayed or when rainfall uncertainty reduces the effective growing period. Drought-tolerant genotypes may maintain comparatively better physiological performance under moisture-limited conditions; however, their effectiveness depends on genotype, soil characteristics, crop developmental stage and stress intensity. Crop choice should therefore be based on local rainfall patterns, soil properties, crop duration, irrigation availability, market conditions and technical recommendations. Maintaining seed stocks of alternative short-duration crops provides flexibility for contingency responses. Following a delayed onset of monsoon, farmers may need to shift from long-duration crops to shorter-duration alternatives, adjust plant density or modify cropping patterns to ensure completion of the crop life cycle within the available moisture.

6. Rainwater Harvesting and Soil-Moisture Conservation

Effective dryland water management seeks to capture rainfall, minimize unnecessary losses and increase the proportion of water retained within the crop root zone. Structural interventions such as farm ponds, contour bunds, graded bunds, trenches, vegetative barriers and check dams can reduce runoff and enhance infiltration when appropriately designed for local soil, slope and watershed conditions. At the field scale, mulching can reduce evaporation, moderate soil temperature, suppress surface degradation and protect soil against erosion (Demo and Bogale, 2024). Retaining crop residues can improve soil cover, infiltration, organic carbon inputs and erosion control, although residue availability must be balanced against livestock-feed requirements.

Soil organic matter is particularly important for long-term dryland productivity because it contributes to soil aggregation, microbial activity, infiltration and water-retention capacity. Improved soil structure enables more effective rainfall infiltration and increases the volume of water that can be stored for subsequent crop uptake. Thus, soil-health improvement and rainfall-conservation measures should be implemented as complementary components of integrated dryland management.

7. Efficient Use of Limited Irrigation Water

Supplemental irrigation can substantially reduce crop losses during periods of inadequate rainfall, although water availability is often insufficient for complete crop irrigation in dryland systems. The management objective should therefore be to maximize crop productivity per unit of available water through strategic irrigation rather than attempting to satisfy the entire seasonal water requirement. Irrigation decisions should account for soil-moisture status, crop developmental stage, atmospheric demand, crop water requirements and the anticipated duration of rainfall deficiency. Priority should generally be given to physiologically sensitive stages, including flowering, pod development and grain formation, when water stress can cause disproportionate yield losses.

Drip and sprinkler irrigation systems can enhance water application efficiency across crops and production systems (Ahmed *et al*., 2023). However, the adoption of advanced irrigation technologies alone does not guarantee efficient water use, as appropriate irrigation scheduling is equally important. Applying irrigation when soil moisture is already adequate may offer limited additional benefits, whereas delaying irrigation until severe water stress develops can adversely affect crop growth and recovery. Therefore, demand-based irrigation scheduling is essential for optimizing water-use efficiency, maintaining crop productivity, and stabilizing yields under variable climatic conditions.

8. Diversification and Integrated Farming

Reliance on a single crop can increase exposure to both climatic fluctuations and market instability. Diversification distributes production risk among crops that differ in maturity period, rooting characteristics, water requirements and economic value. Intercropping cereals with compatible pulses can improve the utilization of available land and environmental resources while providing multiple food and income products. Cereal-pulse combinations may also contribute to nutritional security and resource-use efficiency, although their suitability depends on local rainfall, soil conditions, crop compatibility, market opportunities, and farmers' management capacity.

Integration of livestock can further strengthen whole-farm resilience. Crop residues provide feed resources, while livestock manure returns nutrients and organic matter to agricultural soils. During years of poor crop performance, livestock products can provide an alternative source of food and household income. However, sustainable livestock integration requires advance planning for fodder, water and animal health during drought periods. Thus, diversification should be viewed as an integrated whole-farm strategy encompassing crops, livestock, soil resources, water management and income generation rather than simply increasing the number of cultivated crops.

9. Role of Weather Information and Farmer Knowledge

Reliable weather and climate information can strengthen the timing and effectiveness of agricultural decisions. Short-range forecasts can inform irrigation, fertilizer application, pest and disease management and other immediate operations, whereas seasonal climate information can support crop selection, sowing decisions and contingency planning (Jagriti *et al*., 2023). The value of scientific forecasts is enhanced when they are interpreted alongside field observations and farmers' accumulated knowledge. Farmer possess valuable location-specific understanding of rainfall behaviour, soil responses, sowing opportunities and crop performance developed through long-term experience. Scientific information should therefore complement rather than replace this experiential knowledge.

Emerging agricultural decision-support systems increasingly combine weather forecasts, soil-moisture observations, remote-sensing data and crop models to generate location-specific recommendations. Their effectiveness, however, depends on forecast skill, accessibility, communication, institutional support and farmers capacity to implement recommendations. Integrating scientific climate information with field-based observations and local knowledge can provide a stronger foundation for adaptive decision-making.

10. Towards Climate-Resilient Dryland Agriculture

Climate resilience requires a shift from responding to drought after severe crop stress has developed toward proactive management of climatic risk. Farm preparedness should include maintaining alternative seed stocks, conserving soil moisture, harvesting runoff, securing fodder reserves, identifying supplementary water sources and developing contingency cropping strategies. Institutional mechanisms are equally important. Access to quality seed, reliable climate information, crop insurance, agricultural credit, extension services and locally appropriate contingency plans can substantially improve farmers' adaptive capacity. Climate adaptation should therefore be regarded as a shared responsibility involving farmers, agricultural research institutions, extension agencies and policy systems.

ENSO can provide useful information about the likelihood of large-scale climate anomalies, but it should not be used as an independent basis for farm-level decisions. Effective planning requires the combined interpretation of seasonal climate forecasts, observed rainfall, soil moisture, crop condition and local advisories. Adaptation measures that remain beneficial across a range of rainfall scenarios, such as rainwater harvesting, soil-moisture conservation, crop diversification, improved soil health and efficient water use, are particularly valuable for reducing climate risk.

CONCLUSION

Rainfall variability remains a major constraint on agricultural production and a significant source of livelihood risk in dryland farming systems. El Niño should be regarded as an important indicator of potential climate risk rather than a definitive predictor of drought. Building resilience therefore requires a comprehensive approach that integrates locally adapted crops and varieties, rainwater harvesting, soil-moisture conservation, improved soil health, efficient supplemental irrigation, and diversified crop–livestock systems. Weather forecasts and agricultural advisories can facilitate timely farm-level decisions, particularly when complemented by field observations and farmers' indigenous knowledge. Effective adaptation ultimately depends on maximizing the efficiency with which available rainfall is captured, conserved, and converted into crop and livestock production. Protecting crops during moisture-sensitive growth stages and diversifying livelihood options can further reduce vulnerability to climatic uncertainty. Thus, climate-resilient dryland agriculture depends on managing uncertainty through informed decision-making, efficient resource use, and locally appropriate farming strategies.

Future Perspective

The central challenge of dryland agriculture is the uncertainty associated with the timing, quantity, intensity and spatial distribution of rainfall rather than simply low annual precipitation. El Niño can influence regional agricultural conditions through large-scale ocean-atmosphere interactions, but its effects at individual farm level are mediated by local climate, soil properties, crop characteristics, management practices and water availability. Resilient dryland systems should therefore focus on maximizing the capture, storage and productive use of effective rainfall event. Appropriate crops and varieties, rainwater harvesting, soil-moisture conservation, improved soil health, strategic supplemental irrigation, crop diversification and livestock

integration can collectively reduce vulnerability. When rainfall onset is delayed, contingency cropping can reduce production risk; when rainfall occurs, conservation practices can increase soil-water storage and when water becomes limiting, strategic irrigation can protect crops during critical developmental stages. In this framework, climate information becomes most valuable when it is translated into timely, practical farm-management decisions.

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