

Rainfall Variability and Climate-Resilient Extension Interventions in Eluru and West Godavari Districts of Andhra Pradesh under El Niño-Focused Preparedness, 2026

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Abstract

Rainfall variability during the southwest monsoon is a major determinant of agricultural water availability in coastal Andhra Pradesh. This study integrates mandal-wise rainfall information for the period 01 June–28 September 2026 with the climate-resilient extension activities documented by Dr. YSR Horticultural University–Krishi Vigyan Kendra (KVK), Venkataramannagudem during July–August 2026. The supplied rainfall figures compared normal and actual cumulative rainfall for 28 mandals of Eluru district and 21 mandals of West Godavari district. According to the accompanying rainfall-status distribution figures, 18 of 21 West Godavari mandals (85.7%) were classified as deficient and three (14.3%) as normal, whereas in Eluru district 18 of 28 mandals (64.3%) were deficient, nine (32.1%) normal and one (3.6%) excess. Across both districts, 36 of 49 mandal observations (73.5%) were classified as deficient, 12 (24.5%) as normal and one (2.0%) as excess. The mandal-wise bar charts further demonstrate substantial spatial variation between normal and actual rainfall. These rainfall observations were considered alongside 14 documented KVK extension events covering moisture conservation, efficient irrigation, rainwater harvesting, soil-test-based nutrient management, integrated pest management, pre-monsoon dry sowing, seed pelleting, alternate wetting and drying (AWD), natural farming, integrated farming systems, fodder management, and fisheries and livestock preparedness. The study is descriptive and does not establish a causal relationship between El Niño and observed rainfall at mandal level, because raw meteorological series, anomaly calculations and statistical attribution were not supplied. Nevertheless, the combined evidence supports the importance of location-specific contingency planning, water management, soil-health management and diversified farming-system approaches for climate-risk preparedness. Future KVK evaluations should integrate raw rainfall data,

crop-weather observations, farmer knowledge and adoption indicators, and farm-level productivity and economic outcomes.

Keywords: El Niño; rainfall variability; climate resilience; Eluru; West Godavari; Andhra Pradesh; Krishi Vigyan Kendra; moisture conservation; contingency planning; integrated farming system

1. Introduction

Rainfall is a critical climatic input for agricultural production in India, particularly where crop establishment, irrigation demand and groundwater recharge are closely linked with the southwest monsoon. Rainfall variability may occur both spatially and temporally, producing localized moisture stress in one area and relatively favourable or excessive rainfall in another. Research from India has shown that El Niño episodes can be associated with reductions in southwest monsoon rainfall and can influence crop productivity, although the magnitude and direction of effects vary by location and crop (Dakhore et al., 2020). Studies of Andhra Pradesh and adjoining coastal regions have likewise emphasized the importance of understanding rainfall variability for agricultural planning and water-resource decisions (Samui et al., 2013).

The Indian Meteorological Department has documented a variable relationship between El Niño events and southwest monsoon rainfall rather than a deterministic one; historical El Niño years have included both deficient and near-normal monsoon seasons. Therefore, local rainfall observations should be interpreted together with broader climate drivers rather than attributing every local departure from normal directly to El Niño (India Meteorological Department, n.d.).

During 2026, Dr. YSRHU–KVK, Venkataramannagudem undertook a series of awareness programmes, demonstrations, farmer–scientist interactions and allied-sector advisories focused on preparedness for anticipated El Niño-related climatic stress. The supplied KVK report documents 14 distinct extension events during July–August 2026, addressing agriculture, horticulture, fisheries, livestock, soil health and integrated farming systems. The interventions included moisture conservation, mulching, rainwater harvesting, efficient irrigation, soil-test-based nutrient management, integrated pest management, pre-monsoon dry sowing, seed pelleting, AWD, natural farming and farm diversification (Dr. YSRHU–KVK, 2026).

Contingency planning is an established component of climate-risk management in Indian agriculture. District-level contingency planning under ICAR and associated institutions has been developed to provide location-specific responses to weather aberrations and extreme events (Sikka et al., 2016; Srinivasa Rao et al., 2020). In this context, the rainfall information supplied for Eluru and West Godavari provides an important local diagnostic layer for interpreting the need for water-saving and climate-resilient extension interventions.

The present study therefore combines the supplied rainfall-status figures with the documented KVK programme record. The purpose is not to attribute rainfall departures statistically to El Niño, but to characterize the observed rainfall situation and examine how the KVK extension portfolio corresponded to the management challenges implied by the rainfall distribution.

2. Objectives

- To characterize mandal-wise differences between normal and actual cumulative rainfall from 01 June to 28 September 2026 in Eluru and West Godavari districts.

- To summarize the distribution of rainfall-status categories shown in the supplied district figures.
- To document and synthesize the climate-resilient extension interventions undertaken by Dr. YSRHU–KVK, Venkataramannagudem during July–August 2026.
- To examine the relevance of water, soil, crop, livestock and fisheries management measures to the observed rainfall variability.
- To identify methodological and data gaps for future quantitative evaluation of climate-resilient extension programmes.

3. Materials and Methods

3.1 Study area and source materials

Two districts of Andhra Pradesh—Eluru and West Godavari—were considered for the rainfall analysis. The rainfall period represented in the supplied figures was 01 June to 28 September 2026. The rainfall information was available as mandal-wise bar charts comparing normal and actual cumulative rainfall and as district-level pie charts showing rainfall-status categories. The extension component was based on the supplied KVK programme document covering July–August 2026, which records 14 distinct events and their technical themes, locations and selected participation details.

3.2 Rainfall analysis

The rainfall figures were treated as graphical secondary data. The number of mandals represented in the figures was counted, and the proportions of the rainfall-status categories were taken directly from the supplied pie charts. For Eluru, the figure reports 64.3% deficient, 32.1% normal and 3.6% excess. For West Godavari, it reports 85.7% deficient and 14.3% normal. Counts were obtained by applying the displayed percentages to the number of mandals shown: 28 mandals for Eluru and 21 for West Godavari. The combined distribution was calculated from these counts. Because the raw normal and actual rainfall series and the formal classification thresholds were not supplied, no independent anomaly or significance test was attempted.

3.3 Extension-programme analysis

Each separately documented KVK programme was treated as one extension event. Events were organized into five thematic domains: (i) climate-risk awareness, (ii) water and moisture management, (iii) soil and nutrient management, (iv) crop- and enterprise-specific contingency measures, and (v) integrated and allied-sector resilience. Participation was reported only where the source document provided numbers; no aggregate attendance was estimated.

4. Results and Discussion

4.1 Mandal-wise rainfall variability

The supplied mandal-wise rainfall charts show clear spatial heterogeneity between normal and actual cumulative rainfall in both districts. In Eluru, the normal-versus-actual bars vary markedly among mandals, indicating that district-level averages alone would not adequately describe local rainfall conditions. West Godavari also shows pronounced inter-mandal differences, with several locations displaying sizeable departures between normal and actual rainfall. Such spatial heterogeneity is important for extension planning because crop water requirements, irrigation availability and contingency measures need to be adjusted to local conditions rather than applied uniformly.

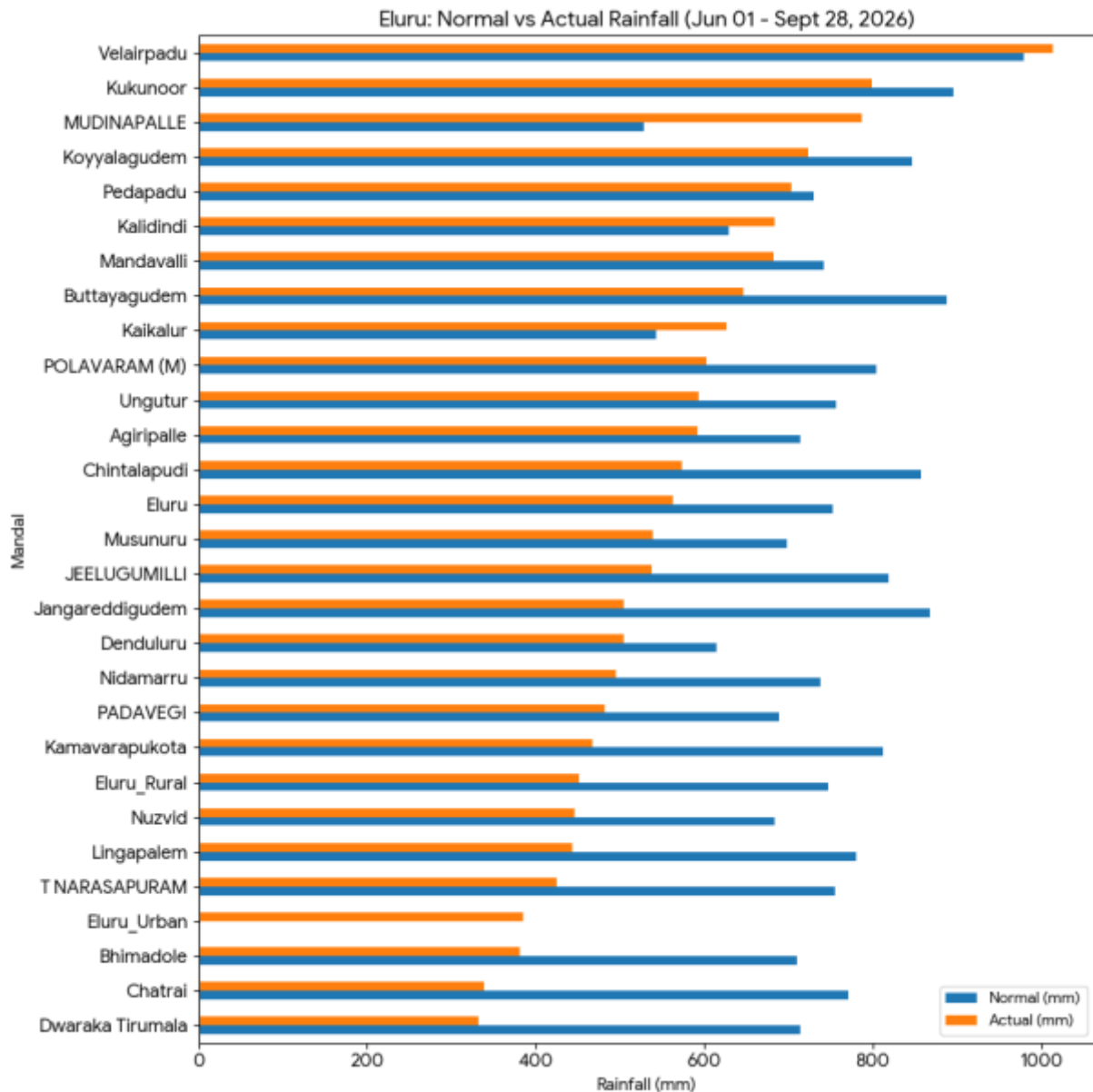


Figure 1. Mandal-wise comparison of normal and actual cumulative rainfall in Eluru district, 01 June–28 September 2026 (supplied graphical data).

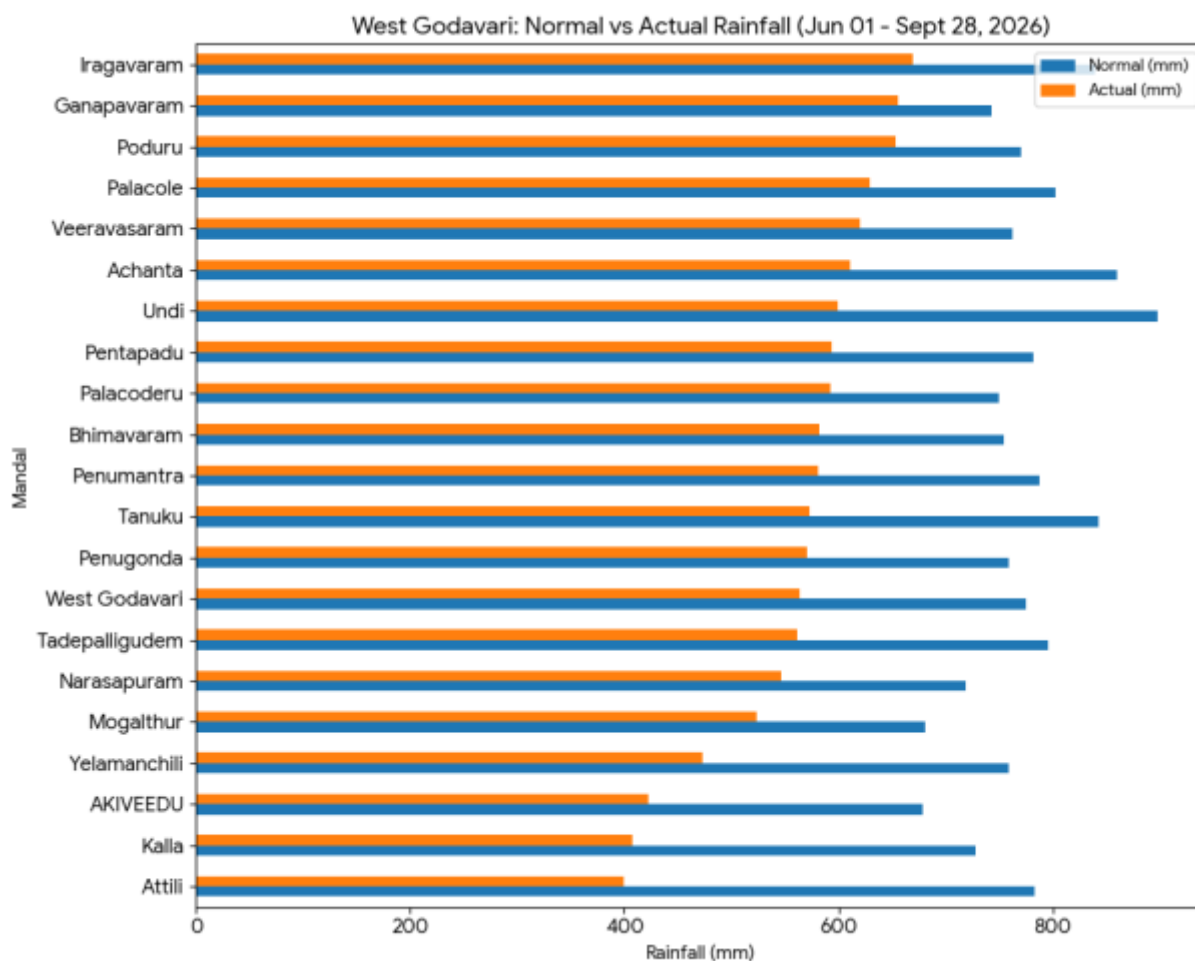


Figure 2. Mandal-wise comparison of normal and actual cumulative rainfall in West Godavari district, 01 June–28 September 2026 (supplied graphical data).

4.2 Rainfall-status distribution

The district-level status figures indicate that deficient rainfall was the dominant category in both districts. In West Godavari, 18 of 21 mandals (85.7%) were classified as deficient and three (14.3%) as normal, with no excess category shown. In Eluru, 18 of 28 mandals (64.3%) were classified as deficient, nine (32.1%) as normal and one (3.6%) as excess. Combining both districts gives 36 deficient, 12 normal and one excess mandal observation, equivalent to 73.5%, 24.5% and 2.0%, respectively.

District	Mandal observations	Deficient	Normal	Excess
Eluru	28	18 (64.3%)	9 (32.1%)	1 (3.6%)
West Godavari	21	18 (85.7%)	3 (14.3%)	0 (0.0%)
Combined	49	36 (73.5%)	12 (24.5%)	1 (2.0%)

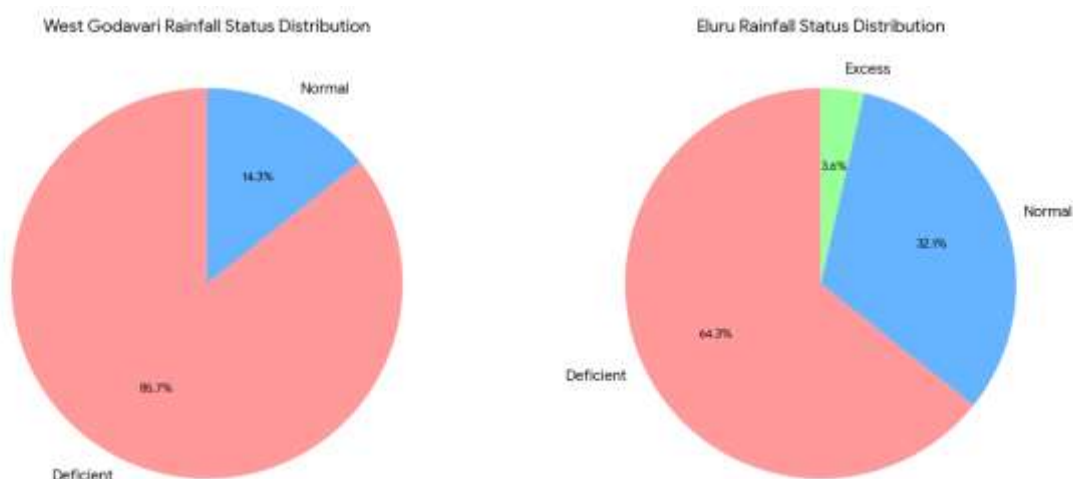


Figure 3. Rainfall-status distribution in Eluru and West Godavari districts, based on the supplied figures for 01 June–28 September 2026.

The predominance of the deficient category provides a strong operational justification for emphasizing water budgeting, soil-moisture conservation and contingency planning during the extension period. However, the classification shown in the supplied figures should not be interpreted as proof that El Niño alone caused the observed rainfall situation. El Niño influences the probability of monsoon anomalies, while Indian monsoon rainfall is also affected by other large-scale and regional processes (India Meteorological Department, n.d.; Dakhore et al., 2020). Consequently, the rainfall figures are best used as a local management indicator.

4.3 Documented KVK climate-resilient extension interventions

Date	Location	Primary focus	Major technical components
06 Jul 2026	Seethappagudem, Buttaigudem	Climate-resilient horticulture + TSP	Pre-monsoon dry sowing; seed pelleting; intercropping; input distribution
10 Jul 2026	Nallajerla	Agriculture and horticulture	El Niño awareness; nutri-garden; oil palm and cocoa management
10 Jul 2026	Fish Seed Farm, Badampudi	Fisheries	Fish breeding/seed production; El Niño preparedness; fish consumption awareness
14 Jul 2026	State-level workshop	Horticultural crops	Climate-resilient management; farmer constraints; scientific advisories

18 Jul 2026	Singarajupalem, Nallajerla	Horticulture and allied crops	APCNF; PMDS; drum seeder; oil palm; IFS; livestock/fisheries integration
23 Jul 2026	Pedavegi	Soil health	Soil sampling/testing; balanced fertilization; soil-health education
28 Jul 2026	KVK-linked Udyana Yatra	Experiential learning	IFS; mushroom; apiary; vermicompost; azolla; fodder; nursery; protected cultivation
30 Jul 2026	Aragallu	Horticulture and allied crops	Climate-resilient practices; IFS; biofertilizers
03 Aug 2026	KVK, Venkataramannagudem	Agriculture and allied activities	El Niño awareness; seed pelleting under PMDS
04 Aug 2026	Marellamudi, Nallajerla	Horticulture and agriculture	Seed pelleting; AWD in paddy; water-saving practices
05 Aug 2026	Musallakunta, Nallajerla	Horticulture + fisheries/livestock	Oil palm/coconut contingency; fish-pond and livestock precautions; 30 farmers
07 Aug 2026	Department of Fisheries, Eluru	Fisheries and livestock	Water quality/levels; aeration; feed; shade; ventilation; drinking water; 20 farmers
11 Aug 2026	KVK, Venkataramannagudem	Soil resilience/natural farming	Beejamrutham with FYM; microbial activity; nutrient availability; soil health
14 Aug 2026	Eluru	Fodder + fisheries/livestock	Improved fodder; CoFS-33; fish-pond precautions; heat-stress management; 20 farmers

The programme portfolio was multidisciplinary. The KVK report identifies moisture conservation, mulching, basin management, contour bunding, half-moon trenches, rainwater harvesting, farm ponds, efficient irrigation and life-saving irrigation as important water-management measures. For paddy, AWD was specifically emphasized in the 04 August programme, while seed pelleting was demonstrated as a crop-establishment measure under stress. The extension strategy also linked soil health with climate

resilience through soil-test-based fertilizer use, organic manures, biofertilizers and micronutrients (Dr. YSRHU–KVK, 2026).

4.4 Water and moisture conservation

Water management was a central component of the documented KVK response and is consistent with the requirements of rainfall-deficit environments. Rainwater harvesting, farm ponds, efficient irrigation, mulching and life-saving irrigation can reduce the sensitivity of crops to irregular rainfall by improving the timing and efficiency of water use. AWD in rice is particularly relevant where irrigation water is constrained. A meta-analysis of 56 studies and 528 paired comparisons found that mild AWD reduced water use by about 23% without significant yield reduction in most circumstances, while severe AWD could reduce yield under unsuitable conditions (Carrijo et al., 2017). Therefore, the KVK recommendation to use AWD should be interpreted as a managed water-saving practice rather than simply allowing severe soil drying.

4.5 Soil health and nutrient management

Rainfall deficiency can interact with nutrient availability because inadequate soil moisture may restrict nutrient movement and root uptake. The KVK programme therefore linked soil testing with balanced fertilizer application, organic manures, biofertilizers and micronutrients. This approach is consistent with climate-smart agriculture principles, which emphasize resource-use efficiency, improved soil management and adaptation to climatic variability. At the field level, soil-test-based nutrient management can help avoid unnecessary nutrient application while maintaining crop nutrition under variable moisture conditions.

4.6 Crop-specific and enterprise-specific contingency planning

The KVK interventions did not rely on a single generalized recommendation. Oil palm, cashew, cocoa, coconut, paddy and other horticultural crops received crop-specific advisories involving irrigation, moisture conservation, nutrient management and pest and disease monitoring. Such localization is important because crop response to rainfall deficit depends on rooting depth, phenological stage, soil characteristics and access to irrigation. Indian contingency-planning literature similarly emphasizes location-specific responses to weather aberrations and the use of district-level contingency plans (Sikka et al., 2016; Srinivasa Rao et al., 2020).

4.7 Integrated farming, fisheries and livestock preparedness

The extension response extended beyond crop production. Integrated Farming Systems (IFS) were promoted to diversify farm activities and reduce dependence on a single enterprise. Indian research reviews indicate that well-managed IFS can improve resource-use efficiency, provide complementary enterprises and strengthen livelihood resilience of small and marginal farms (Singh et al., 2020). In the KVK programme, fisheries advisories covered water quality, water level, aeration and feed management, while livestock guidance emphasized drinking water, shade, ventilation and heat-stress protection. This interdisciplinary approach is appropriate where farm households combine crops with livestock and fisheries.

4.8 Extension methods and participation

The documented programmes used expert lectures, farmer–scientist interaction, field demonstrations, exposure visits, practical demonstrations and input distribution. Participant numbers were available for selected programmes: 30 farmers on 05 August, 20 farmers on 07 August and 20 farmers on 14 August 2026. The source document does not provide standardized attendance data for all 14 events, so an overall participation total was not estimated. The combination of practical demonstrations and direct

farmer interaction is important because climate-resilient technologies often require site-specific adaptation and confidence in implementation.

4.9 Alignment between rainfall evidence and extension response

The rainfall-status figures and KVK programme record show a logical correspondence at the level of preparedness: a high proportion of mandal observations were classified as deficient, while the extension portfolio strongly emphasized water conservation, efficient irrigation, soil moisture management, contingency planning and enterprise diversification. This alignment should be described as programmatic relevance rather than measured impact. The available materials do not permit estimation of the amount of water saved, yield protected, income generated or adoption achieved as a result of the interventions.

5. Implications for Climate-Resilient Agricultural Extension

- Use mandal-level rainfall monitoring as a routine trigger for location-specific crop and water advisories rather than relying only on district averages.
- Prioritize water budgeting, rainwater harvesting, farm ponds, mulching and efficient irrigation where rainfall deficiency is persistent.
- Promote carefully managed AWD in paddy where irrigation infrastructure and soil conditions permit, with monitoring to avoid excessive drying.
- Integrate soil testing and balanced nutrient management with moisture conservation because water and nutrient management are closely linked.
- Combine crop-specific contingency measures with integrated farming, livestock and fisheries preparedness for diversified farm households.
- Link input distribution with technical follow-up so that seed, biofertilizer and fodder support is accompanied by appropriate management advice.
- Develop baseline and endline measurements of farmer knowledge, technology adoption, water use, crop yield and farm economics to quantify extension outcomes.

6. Limitations

The rainfall component is based on supplied graphical summaries rather than raw station or mandal time-series data. Consequently, exact rainfall anomalies, temporal dry-spell characteristics, coefficient of variation, rainfall intensity and statistical significance could not be independently calculated. The rainfall-status classification thresholds used to generate the supplied pie charts were also not provided. Furthermore, the study does not contain a control group, pre- and post-intervention knowledge scores, systematic adoption measurements, crop-yield records or economic impact data. Accordingly, the findings should be interpreted as a descriptive synthesis of rainfall conditions and climate-resilient extension preparedness rather than as a causal evaluation of programme effectiveness or an attribution study of El Niño.

7. Conclusion

The supplied rainfall figures for 01 June–28 September 2026 indicate substantial spatial variability and a predominance of deficient rainfall classifications across Eluru and West Godavari districts. Of the 49 mandal observations represented, 36 (73.5%) were classified as deficient, 12 (24.5%) as normal and one (2.0%) as excess. Against this rainfall context, Dr. YSRHU–KVK, Venkataramannagudem implemented

a broad climate-resilient extension programme during July–August 2026, encompassing moisture conservation, efficient irrigation, AWD, soil-health management, crop-specific contingency practices, integrated farming, fisheries and livestock preparedness, demonstrations and farmer–scientist interaction. The evidence demonstrates strong alignment between the documented extension themes and the management needs associated with rainfall variability. However, the study does not establish that the rainfall deficiency was caused by El Niño or that the extension interventions produced quantified improvements in productivity or farmer income. Future research should combine high-resolution rainfall and weather data with farmer-level adoption, crop performance, water-use efficiency and economic indicators to evaluate the effectiveness of climate-resilient extension interventions.

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