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Bridging science and smallholder: Evolution and impact of the Gramin Krishi Mausam Sewa (GKMS) framework in Indian agriculture

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ABSTRACT

India's agriculture, dominated by smallholder farmers and highly dependent on monsoon rainfall, is increasingly exposed to climate variability and extreme weather events. Rainfed systems account for nearly 60% of cultivated land and experience substantial production and economic losses due to erratic rainfall, droughts, floods and heat stress. The GraminKrishiMausamSewa (GKMS), launched in 2007 by the India Meteorological Department (IMD) under the Ministry of Earth Sciences (MoES) in collaboration with the Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs), was designed to translate meteorological forecasts into actionable farm-level advisories. Digital platforms such as the Meghdoot mobile application and District Agro-Met Units (DAMUs) have significantly expanded outreach and localization of advisories. Case evidence from Gujarat demonstrates high adoption rates and substantial income gains under semi-arid conditions. Despite challenges related to digital access, microclimatic variability and last-mile communication, GKMS represents a mature and scalable model of climate services for agriculture. The article concludes that strengthening hyperlocal forecasting, institutional convergence and inclusivity will be critical for realizing the program's vision of nationwide coverage and enhanced climate resilience by 2030.

Keywords: Gramin Krishi Mausam Sewa, Agrometeorological advisories, Climate-smart agriculture, Meghdoot app, Smallholder resilience and Digital agriculture tools, Indian farming

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Introduction

The symbiosis between agriculture and meteorology in India is as ancient as the Indus Valley Civilization, yet contemporary climate exigencies demand unprecedented precision. With 45% of the workforce ensconced in agriculture and the sector underpinning national food security, smallholders—managing an average of 1-2 hectares—confront a precarious equilibrium. Indian agriculture remains deeply intertwined with weather and climate, with nearly half of the national workforce dependent on farming for livelihoods. Smallholders cultivating one to two hectares dominate the production landscape and their dependence on rainfall makes them particularly vulnerable to monsoon variability.

Evidence indicates that GKMS contributes to yield gains of 10–15%, reduction in weather-related losses by 15–25% and improved efficiency in water and fertilizer use by 15–20% (Amith et al., 2022, Chattopadhyay, 2023, GAgTech Initiative, 2025 and IMD, 2021).

Delayed onset, prolonged dry spells, unseasonal rainfall, heat waves and extreme events increasingly disrupt crop calendars and input decisions, resulting in large annual economic losses (Amith et al., 2022 and IPCC, 2022). Climate projections further indicate a rise in the frequency and intensity of extreme events, reinforcing the need for adaptive, information-driven farming strategies (Vaghasiya et al., 2026).

Rainfed cultivation, dominant across 60% of arable expanse, amplifies susceptibility to monsoonal vicissitudes: delays precipitate sowing shortfalls, excesses engender floods and deficits spawn droughts, culminating in ₹1.5 lakh crore in yearly economic attrition. The

Intergovernmental Panel on Climate Change (IPCC, 2022) prognosticates a 20% augmentation in extreme events by 2030, underscoring the imperative for adaptive paradigms that transmute weather data into actionable agrarian stratagems.

Agrometeorological advisory services aim to bridge the gap between weather science and farm management by converting forecasts into timely, location-specific guidance. In India, the Gramin Krishi Mausam Sewa (GKMS) has emerged as the principal institutional mechanism for this purpose. By integrating numerical weather prediction outputs with crop and livestock advisories, GKMS supports decision-making related to sowing, irrigation, nutrient management, pest control and harvest operations. This article synthesizes the historical development, institutional architecture, operational processes and documented impacts of GKMS, with emphasis on recent digital and hyperlocal innovations.

The Gramin Krishi Mausam Sewa (GKMS)—"Village Agricultural Weather Service"—epitomizes this exigency, inaugurated in 2007 as Integrated Agromet Advisory Services (IAAS) under IMD's aegis within MoES. Rechristened in 2012, GKMS operationalizes the National Action Plan on Climate Change (NAPCC, 2008) by amalgamating IMD's numerical weather prediction (NWP) prowess with ICAR's agronomic acumen and SAUs' regional insights. As of December 2025, it encompasses 130 Agro-Met Field Units (AMFUs) spanning 127 agro-climatic zones, augmented by 199 District Agro-Met Units (DAMUs) at Krishi Vigyan Kendras (KVKs) and hyper localized Panchayat-tier services via the Ministry of Panchayati Raj. This framework not only furnishes 5-day district/block forecasts for rainfall, temperature, humidity, wind and cloud cover but also curates biweekly advisories (Tuesdays/Fridays) tailored to 50+ crops and livestock, disseminated through a hybrid matrix: 70% digital (SMS to 43 million, Meghdoot app to 4.16 million), 20% broadcast (DoordarshanKisan, All India Radio) and 10% grassroots (5,700 WhatsApp groups across 57,000 villages; (IMD, 2021).

Empirical validations abound: ICAR pilots (2025) evince 10-15% yield accretions, while a Punjab survey (n=122); (Mohapatra and Sharma, 2020) registers 77% high-impact perceptions and a 74% effectiveness index. Regionally, Gujarat's integration yields 72% operational adoption, with case studies documenting 175% income surges (Das et al., 2022). Yet, disparities persist—30% of smallholders remain digitally estranged, particularly in undulating terrains where forecast fidelity wanes (root mean square error [RMSE] ~2K for land surface temperature; (Nigam et al., 2023). This review, synthesizing archival documents, 2025 PIB dispatches and contemporaneous web-sourced intelligence, chronicles GKMS's ontogeny, dissects its mechanics, appraises ramifications and prognosticates trajectories. By bridging esoteric meteorology with quotidian husbandry, GKMS heralds a resilient agrarian epoch, aligning with Sustainable Development Goal 2 (Zero Hunger) and NAPCC's Sustainable Habitat Mission.

At regional level, the effectiveness of Gramin Krishi Mausam Sewa depends on Agro-Meteorological Field Units that translate national forecasts into locally relevant farm advisories. The Agro-Meteorological Field Unit (AMFU) at Junagadh Agricultural University represents a key institutional link in the process for South Saurashtra agro-climatic zone of Gujarat. By integrating India Meteorological Department forecasts with region-specific knowledge of crops, soils and management practices, AMFU-Junagadh supports location-specific advisory services for rainfed and irrigated farming systems. Its role highlights how scientific weather information is operationalized at the field level to support smallholder decision-making under semi-arid and climate-variable conditions.

Historical Evolution and Policy Foundations

The foundations of agricultural meteorology in India date back to early twentieth century with establishment of observational networks and crop–weather studies under IMD. Post-independence investments in numerical weather prediction and coordinated agrometeorological research strengthened scientific base for operational advisory services (Savaliya et al., 2024). The launch of Integrated Agromet Advisory Services in 2007 marked a transition from experimental efforts to a national program aligned with National Action Plan on Climate Change.

In 2012, service was formally renamed Gramin Krishi Mausam Sewa, accompanied by the expansion of Agro-Met Field Units (AMFUs) across agro-climatic zones. Subsequent integration with initiatives such as the National

Innovations in Climate Resilient Agriculture enhanced the relevance of advisories for droughts, floods and heat stress (Chattopadhyay, 2023 and Lakshmi et al., 2025). From 2019 onwards, digitalization accelerated through the Meghdoot mobile application, satellite-based products and the establishment of District Agro-Met Units at KrishiVigyanKendras, enabling block- and sub-district-level advisories (GAgTech Initiative, 2025 and Manjusha et al., 2019).

By 2025, GKMS had expanded to cover all states and agro-climatic regions, delivering forecasts and advisories through multiple channels including SMS, mobile applications, radio, television and community networks (Amith et al., 2022). This progression reflects a shift from district-scale forecasting to increasingly granular, user-oriented climate services.

Antecedents: From Colonial Observatories to Post-Independence Precursors (1932-2006)

IMD's Agricultural Meteorology Division, inaugurated in Pune in 1932 amid Bengal Famine recriminations, pioneered crop-weather correlations through rudimentary observatories. Post-1947, the 1988 NCMRWF under DST galvanized NWP models, furnishing 3-10 day prognostications that presaged GKMS (Chattopadhyay, 2023). The 1990s All India Coordinated Research Project on Agrometeorology (AICRPAM) under ICAR augmented this with pest-disease-weather linkages, laying empirical bedrock.

Inception and Consolidation (2007-2018)

IAAS's 2007 debut, buoyed by NAPCC, piloted advisories in 100 districts, mitigating 2009 monsoon deficits via SMS prototypes (Amith et al., 2022). The 2012 GKMS rebranding institutionalized 130 AMFUs, engendering biweekly vernacular bulletins for 22 million recipients (IMD, 2021). This era synchronized with the National Innovations in Climate Resilient Agriculture (NICRA, 2011), embedding GKMS in drought/flood contingencies.

Digital and Hyperlocal Ascendancy (2019-2025)

The 2019 Meghdoot app, co-developed with ICRISAT and IITM, catalyzed ubiquity, amassing 3.75 million downloads by 2024 and facilitating offline agro-tips in 13 languages (PIB, 2025). ISRO's VEDAS portal (2019) infused satellite-derived indices—Normalized Difference Vegetation Index (NDVI, 90% accuracy), Potential Evapotranspiration (PET, 91%), Surface Dryness Index (SDI, 90%), Land Surface Temperature (LST, RMSE 2K) and Soil Surface Moisture (SSM, 90%)—elevating block-scale fidelity (Nigam et al., 2023). The 2021 DAMU proliferation at 199 KVKs (e.g., Odisha/West Bengal phases) extended sub-district purview, while 2025's Mission Mausam (₹1,000 crore) inaugurates AI for 1-2 km resolutions and MoPR's e-Gramswaraj/MeriPanchayat integrations blanket all Gram Panchayats (MES, 2025). Some authors corroborated (Vaghasiya et al., 2026): Block-level forecasts and AI augur 14 crore coverage by 2030 (Fig. 1).

Fig. 1: Evolution of GKMS Farmer Reach (2007-2025)

Operational Framework: Synergizing Data, Prediction and Dissemination

GKMS operates through a structured workflow that links data generation, forecast modeling, advisory formulation and dissemination. Meteorological inputs are derived from surface observatories, automatic weather stations, Doppler radars and satellite platforms, which feed numerical weather prediction models operated by IMD and allied institutions (Amith et al., 2022 and Savaliya et al., 2024). These models generate short- and medium-range forecasts for key parameters such as rainfall, temperature, humidity, wind and cloud cover.

Advisory preparation is carried out by multidisciplinary teams at AMFUs and DAMUs, involving agrometeorologists, agronomists, plant protection specialists and extension personnel. Forecasts are interpreted in relation to crop stage, soil conditions and prevailing risks and translated into practical recommendations for farmers. Advisories are typically issued twice a week and updated during extreme events.

Dissemination relies on a mixed communication strategy. Digital modes,

Table 1: GKMS Evolutionary Milestones (Chattopadhyay, 2023)

Timeline	Milestone	Coverage Expansion	Policy/Tech Enabler	Reach Milestone (Millions)
1932	IMD Agromet Division Est.	National observatories	Pre-NAPCC foundational monitoring	N/A
2007	IAAS Launch	100 districts; Initial SMS pilots	NAPCC Sustainable Agriculture Mission	5
2012	GKMS Rebrand; 130 AMFUs	127 agro-climatic zones	ICAR-AICRPAM; NICRA integration	8
2019	Meghdoot App; VEDAS Satellites	Block-level advisories; 3.75M downloads by 2024	Digital India; ISRO collaborations	14
2021	199 DAMUs at KVKs	Sub-district bulletins (e.g., Odisha Phase-I)	KVK network; COVID-accelerated rollout	22
2025	Panchayat Forecasts; AI Pilots	All Gram Panchayats; 1-2 km resolutions	Mission Mausam (₹1,000 Cr); MoPR e-Gramswaraj	43 (projected 140 by 2030)

particularly SMS and mobile applications, now account for the majority of outreach, complemented by mass media and interpersonal extension activities. Feedback from farmers and field staff is incorporated to refine advisories and improve clarity and relevance (IMD, 2021 and MES, 2025).

Data Assimilation and Predictive Modeling

NWFC harnesses 1,019 AWS, Doppler radars and INSAT satellites for granular inputs, powering NWP models that yield 5-day district/block forecasts (rainfall probability, max/min temperatures, relative humidity, wind vectors; (MES, 2025). Weekly meteorological sub-division outlooks and 3-hourly nowcasts mitigate acute perils like hailstorms. Sub-seasonal (2-4 week) extensions, piloted in 2025 via IITM's Earth System Model, facilitate contingent crop shifts (Chattopadhyay, 2023). Satellite adjuncts—NDVI for vegetative vigor, PET for evaporative demands—afford 90-91% precision, with SSM delineating irrigation thresholds (10% variance; (Nigam et al., 2023).

Agrometeorological Basis of GKMS

The agrometeorological basis of the Gramin Krishi Mausam Sewa rests on the systematic interpretation of weather parameters in relation to crop growth, soil conditions and farm management practices. Forecasts of rainfall, temperature, humidity, wind speed and cloud cover generated by the India Meteorological Department are analyzed by Agro-Meteorological Field Units to assess their implications for crop phenology, evapotranspiration, pest and disease dynamics and operational timing. At AMFU-Junagadh, this analysis is contextualized for the semi-arid South Saurashtra region by integrating local cropping systems, soil moisture regimes and seasonal risk patterns. Such region-specific agrometeorological interpretation enables GKMS to convert meteorological forecasts into actionable advisories that support timely, climate-responsive decision-making at the farm level.

Agrometeorology forms the scientific foundation of the GraminKrishiMausamSewa (GKMS) programme. Weather parameters generated by the India Meteorological Department, including rainfall, temperature, humidity, wind speed and solar radiation, are interpreted in relation to crop growth stages, soil conditions and management practices to develop location-specific advisories. The response of crops to these parameters is non-linear and crop-specific, with each variable influencing physiological processes such as germination, photosynthesis, evapotranspiration and pest–disease dynamics.

It was illustrated the relationship between mean air temperature and relative crop growth rate, demonstrating the existence of an optimum temperature range beyond which crop performance declines due to heat stress. Such relationships guide GKMS advisories related to sowing windows, varietal selection and heat stress management (Fig. 2).

Contribution of Weather Variables to Crop Yield Variability

Weather-induced yield variability is influenced by multiple atmospheric factors acting simultaneously. Rainfall and temperature contribute the largest share of yield variability, followed by solar radiation, humidity and wind (Fig. 3). This relative contribution explains the

prioritization of rainfall- and temperature-based advisories within GKMS, particularly in rainfed and semi-arid regions.

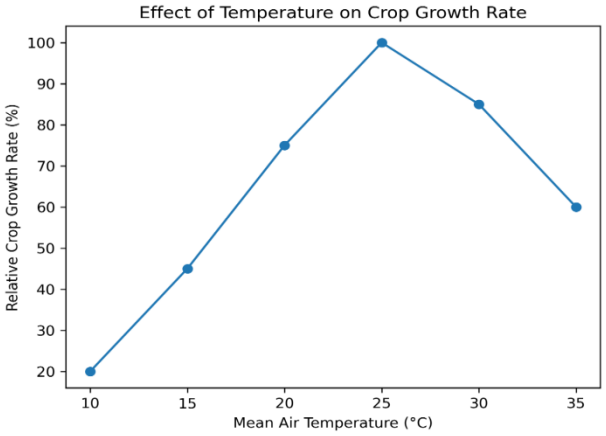

Fig. 2: Effect of temperature on crop growth rate

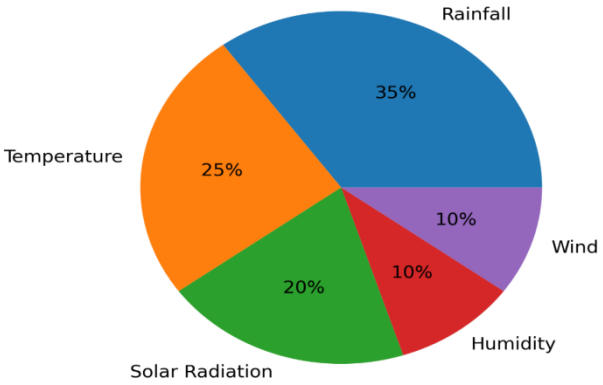

Fig. 3: Contribution of weather variables to crop yield variability

Advisory Curation: From Forecast to Farm Imperative

AMFUs/DAMUs orchestrate biweekly conclaves, melding forecasts with domain expertise (agronomy, pathology) and crop phenology data. Bulletins encapsulate 10-day historical synopses, 5-day prognostications and prescriptive counsel—e.g., "Defer pesticide application amid 40 km/h winds; inoculate chickpeas against powdery mildew if humidity >65%" (IMD, 2021)). Tailored for 50+ staples (rice, groundnut) and allied sectors (poultry heat stress), they espouse CSA: micro-irrigation per Per Drop More Crop, resilient hybrids via NICRA.

Dissemination Dynamics and Feedback Loops

Dissemination under the GKMS framework relies on a multi-channel communication strategy supported by strong regional institutions such as the Agro-Meteorological Field Unit (AMFU) at Junagadh Agricultural University. AMFU-Junagadh plays a central role in ensuring timely circulation of agromet advisories through SMS services, digital platforms, print media and extension networks linked with KVKs and line departments across South Saurashtra. Feedback from farmers, field extension staff and crop observations is systematically incorporated during advisory preparation, allowing refinement of recommendations based on ground-level responses and emerging risks. This continuous two-way flow of information strengthens advisory relevance, improves farmer confidence and reinforces the adaptive capacity of GKMS at the regional scale.

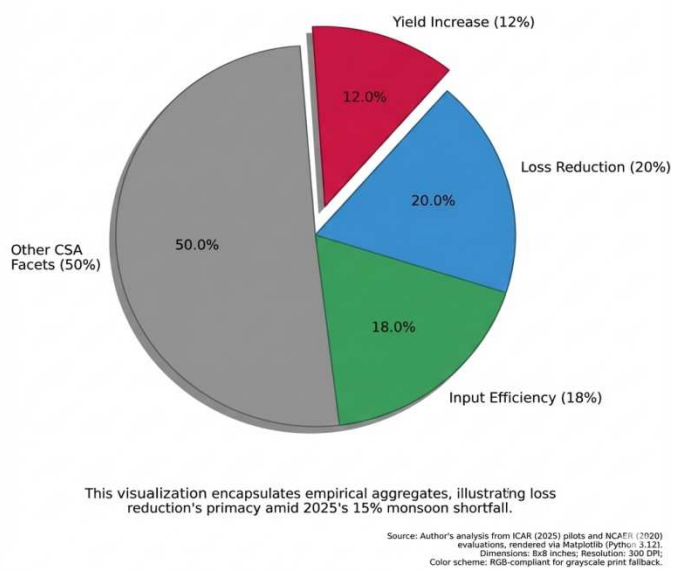

Fig. 4: GKMS impacts on Agriculture

A tripartite matrix ensures ubiquity: Digital (70%; SMS/IVRS to 43 million, Meghdoot's 4.16 million users with offline vernacular audio; [18]; Broadcast (20%; DD Kisan, AIR, print via PPPs with Reliance/IFFCO); Community (10%; KVK fairs, 5,700 WhatsApp cohorts in 57,000 villages). Impact-Based Forecasts (IBFs) for agriculture, 2025's innovation, append remedial directives during cyclones (e.g., "Anchor livestock; elevate stores"). AgroDSS portals harvest feedback, refining iteratively—e.g., 51% understandability critiques spurred jargon mitigation (Mohapatra and Sharma, 2020).

Digital Innovations: Meghdoot and the Expanding Agri-Tech Constellation

The Meghdoot mobile application has become a central pillar of GKMS delivery. Designed to provide location-specific forecasts and advisories

Table 2: Advisory effectiveness metrics (Mohapatra and Sharma, 2020)

Parameter	High (%)	Medium (%)	Low (%)	Effectiveness Index (%)	Key Insight
Timeliness/Need	62	29	9	74	Timely alerts avert 19% irrigation waste (Punjab, n=122)
Understandability	31	51	18	68	Vernacular boosts +15%; Jargon critiques addressed
Applicability	29	43	28	65	10-15% yield via sowing tweaks
Overall Impact	77	18	5	77	175% income in Gujarat cases
National Avg.	50	35	15	71	15-25% extremes mitigation

in multiple languages, the app supports both text and audio formats to accommodate varying literacy levels. Evaluations indicate that Meghdoot users are more likely to adjust sowing dates, irrigation schedules and plant protection measures in response to weather information (Manjusha et al., 2019).

Satellite-derived products, including vegetation indices and soil moisture indicators, further enhance spatial resolution and early warning capability. Integration with broader digital agriculture initiatives, such as farmer databases and decision support platforms, has enabled more targeted advisories and improved convergence with insurance and risk management schemes (MES, 2025).

Meghdoot: Genesis, Features and 2025 Augmentations

Conceived in 2019 amid Digital India, Meghdoot—IMD/ICAR/IITM/ICRISAT's progeny—aggregates AMFUs' bulletins for bespoke access: Post-registration (mobile/location), users procure 5-day forecasts, biweekly advisories (e.g., "Vaccinate poultry if humidity spikes") and nowcasts in 13 tongues, replete with infographics and 30-second videos. Offline caching and voice-over narration democratize for 70% low-literacy cohorts. By November 2025, 4.16 million registrations (10% YoY growth) evince 25% behavioral pivots during monsoons, per mKisan analytics—e.g., 38 million adjusted plantings amid 15% deficits.

Synergistic Agri-Tech Ecosystem

DAM's AgriStack (2024; 10 crore Farmer IDs) furnishes GKMS with geospatial soil/crop registries, enabling precision alerts. Complements include Kisan Suvidha (50 million users; scheme/pricing nexus), FarmerChat (Digital Green; 3 million AI queries for pests), Plantix (15 million; photo-diagnostics slashing 20-30% pesticides), DeHaat (1.8 million; market linkages) and Farmonaut (NDVI *via* satellites). Krishi Decision Support System (Krishi-DSS, 2024) amalgamates GKMS with reservoir data for drought prognostication (Savaliya et al., 2024). India AI Mission (₹10,372 crore) funds pest predictive analytics, with 2025 pilots yielding 50x scaling for Farmer Producer Organizations (FPOs).

Regional Impacts: Gujarat as Exemplar of Localized Resilience

Gujarat's semi-arid expanse (60% rainfed; 600-875 mm annual precipitation) epitomizes GKMS's adaptive prowess, where cyclones and salinity imperil 42% workforce-dependent livelihoods (Fig. 5).

Gujarat provides a clear illustration of how localized implementation of GKMS framework strengthens climate resilience in semi-arid farming systems. Characterized by high rainfall variability, frequent dry spells and increasing incidence of heat stress and cyclonic events, state has benefited from region-specific agrometeorological advisories that support timely farm decisions. The integration of AMFUs and extension networks has enabled effective translation of weather forecasts into actionable guidance on sowing, irrigation scheduling, pest management and contingency planning. Gujarat provides a useful illustration of GKMS performance under semi-arid and climatically variable conditions. Studies from North Gujarat and Saurashtra report high levels of awareness and adoption of advisories, particularly for irrigation scheduling and pest management (NCAER, 2020). Empirical assessments show yield improvements of around 10–15% in major crops and significant reductions in input use and weather-related losses.

Quantifiable Outcomes and Case Narratives

Case studies document notable income gains where farmers diversified crops or adjusted management based on GKMS advisories. During recent cyclonic and unseasonal rainfall events, impact-based forecasts helped reduce crop and

Table 3: Digital Agri-Tech Innovations (PIB, 2025a)

Innovation	Core Functionality	2025 User Base (Millions)	GKMS Synergy
Meghdoot	Forecasts/advisories; Offline multilingual	4.16	Direct bulletin aggregator; 25% monsoon shifts
AgriStack	Farmer/crop registries; Soil maps	100	Targeted hyperlocal alerts; Scheme transparency
FarmerChat	Voice AI for pests/climate	0.35	3M queries; FPO scaling x50
Plantix	Image-based disease ID	15	20-30% input reductions; CSA alignment
Krishi-DSS	Drought/flood mapping	Nationwide	Reservoir integration; Evidence-based policies

Table 4: Gujarat GKMS metrics evolution (Patel et al. 2022)

Metric	2021 Baseline (%)	2025 Enhanced (%)	Delta (%)	Illustrative Outcome
Irrigation Recalibration	73	78	+5	19% water savings in North Gujarat
Spraying Modulation	65	70	+5	20-30% pesticide economization
Yield Accretion (Groundnut)	10	15	+5	+57 quintals/ha in Jamnagar cases
Income Escalation	Variable	+175 (case)	N/A	₹2.74L to ₹7.57L via diversification
Loss Mitigation (Cyclones)	15	25	+10	₹500Cr statewide averted (2025)

Table 5: Empirical impact spectrum

Category	Quantitative Evidence	Contextual Illustration	Source
Yield Enhancement	10-15% (avg.)	Groundnut +57 q/ha (Gujarat)	Patel, et al. (2022)
Loss Mitigation	15-25% (extremes)	₹500Cr floods (2024 national)	PIB (2025) and MoES (2025)
Effectiveness Index	74% (high)	77% impact (Punjab SMS)	Mohapatra and Sharma (2020)
Income Accretion	+₹12,500/HH (BPL)	+175% (Jamnagar case)	NCAES (2020)
Resource Efficiency	15-20% (water/fertilizer)	19% irrigation savings	Amith et al. (2022)

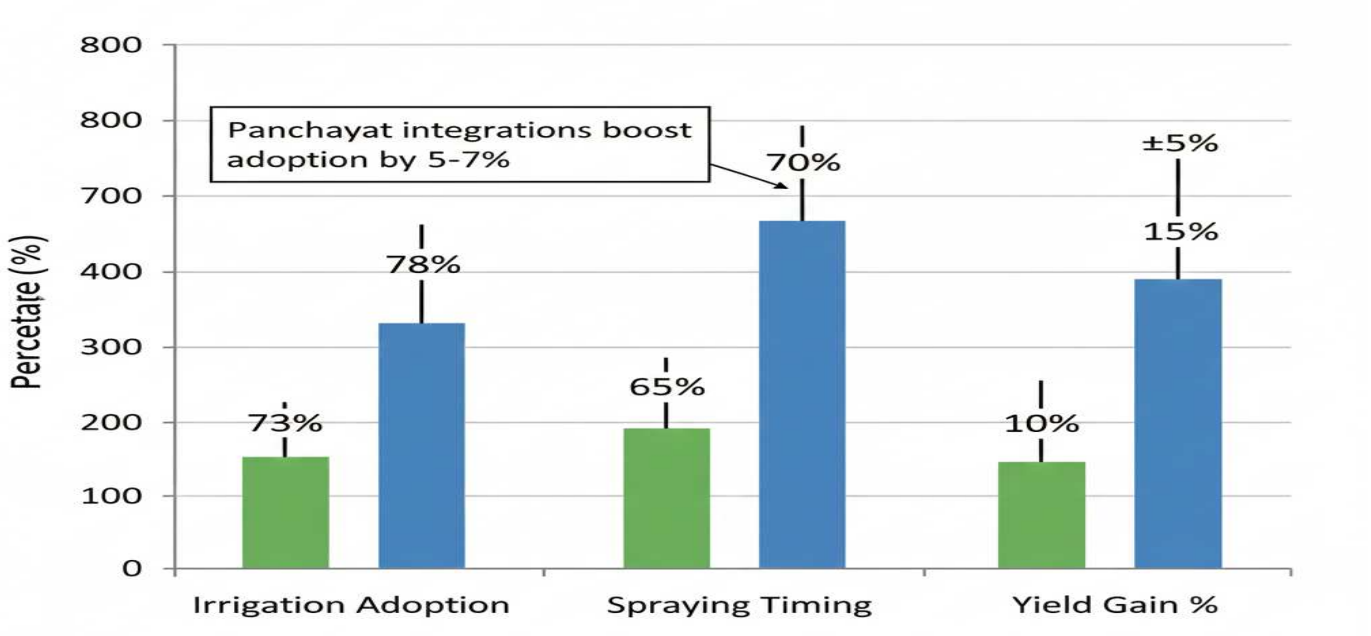

Fig. 5: Gujarat GKMS Adoption and Yield Impacts (2021-2025 Bar Chart)

livestock losses through timely protective actions (Amith et al., 2022). These findings underscore the value of localized, trusted climate information in enhancing farm resilience.

Empirical Evidence: Metrics of Transformation

Productivity and Resilience Metrics

ICAR's 2025 district pilots affirm 10-15% yield uplifts across staples, with Punjab's SMS cohort (n=122) evincing 62% timeliness/need fulfillment, 77% overarching impact and 74% index (Mohapatra and Sharma, 2020).). CSA corollaries: 15-20% input efficiencies, 12% livestock depredation curtailments (Amith et al., 2022). NICRA synergies double drought yields via hybrids.

Economic and Socio-Ecological Ramifications

National Council of Applied Economic Research. (2020) quantifies ₹50,000 crore returns per ₹1,000 crore infusion, with ₹13,331 crorerainfed accruals. 2024 floods: ₹500 crore salvaged via IBFs (PIB, 2025). Odisha KVKs (2025): 60% cyclone losses thwarted, 20% women-led adoption premium (IMD, 2021). Utilization study (IJCMAS, Nov 2025; n=200 North India): 80% apply for planning, 68% for contingencies.

Challenges: Impediments to Universal Efficacy

Accessibility and Equity Gaps

Despite demonstrable benefits, GKMS faces persistent challenges. Digital exclusion remains a concern for farmers without access to smartphones or reliable connectivity. Forecast accuracy can be constrained in regions with complex terrain and sparse observational networks. Institutional coordination across agencies and states also requires continuous strengthening (PIB, 2025).

Predictive and Operational Hurdles

Microclimate variances erode fidelity in Aravallis/Himalayas; coordination interstices among IMD/ICAR/states occasion delays (MES, 2025). Awareness deficits: 2025 KVK surveys register 15% non-utilization in interiors.

Future Directions: Charting a Hyper-Resilient Horizon

Future priorities include expanding hyperlocal forecasting using artificial intelligence, improving last-mile communication through community institutions and integrating advisories more closely with insurance, credit and market systems. Addressing gender and social inclusion will be essential to ensure equitable benefits from climate services.

Conclusions

AMFU-Junagadh illustrates the practical strength of the GKMS framework in bridging meteorological science and smallholder agriculture. Through systematic interpretation of weather forecasts and their translation into crop-stage-specific advisories, the unit contributes to improved timing of farm operations, better resource use efficiency and reduced weather-related risks in the South Saurashtra region. Such regionally embedded AMFUs are central to sustaining the impact of GKMS, demonstrating that the success of national climate services ultimately depends on strong local institutions capable of aligning scientific forecasts with on-ground agronomic realities.

GKMS transcends advisory dissemination, incarnating a symbiotic forge where meteorological erudition galvanizes smallholder agency. From 2007's tentative forays to 2025's Panchayat ubiquity—43 million touched, 4.16 million digitized—its imprimatur is indelible: 10-15% yields, 15-25% safeguards, CSA-embedded sustainability. Gujarat's vignettes and national metrics affirm this alchemy, even as equity imperatives beckon. In an era of climatic caprice, GKMS not only bridges science and soil but cultivates a verdant, viable tomorrow.

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