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Weather-based Agro-advisory Services in India: Current Challenges and Emerging Opportunities

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Historically, farmers in India relied on indigenous weather knowledge and traditional practices to manage climatic risks. While these practices offered resilience, they lacked the precision needed to cope with increasing weather variability and emerging challenges such as heat waves, cyclones, and erratic rainfall. Weather-based agro-advisory services (AAS) are a basis of climate-resilient agriculture in India. With agriculture deeply intertwined with monsoon variability, these services aim

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to reduce weather-related risks by delivering timely and location-specific information to farmers. This paper reviews the evolution of AAS in India, examines current operational challenges, and explores future opportunities driven by technology, institutional reform and participatory approaches. The National Innovation on Climate Resilient Agriculture (NICRA) is a landmark initiative launched by the Indian Council of Agricultural Research (ICAR) in 2011 to address the challenges posed by climate variability and extreme weather events on Indian agriculture. It was noted that one of the evolving strengths of Pradhan Mantri Fasal Bima Yojana (PMFBY)lies in its increasing reliance on weather-based agrometeorological data and advisories to improve risk assessment and expedite claim processing. While weather-based agro-advisory services have certainly made strides in India, they still face significant challenges that hinder their potential to support farmers effectively. Enhanced accuracy, personalisation, and last-mile connectivity are key to making AAS more impactful and inclusive in the face of increasing climate variability.

Keywords: Weather; agro advisory; climate risk; India.

1.INTRODUCTION

India's agriculture is profoundly influenced by the vagaries of weather and climate, particularly due to the country's heavy dependence on the southwest monsoon, which accounts for over 70% of annual rainfall. The increasing frequency of extreme weather events such as droughts, floods, unseasonal rains, and heatwaves,largely attributed to climate change,has further intensified the vulnerability of farming communities. Previous research has shown that climate change may pose a threat to total food productivity. Despite the carbon fertilisation effect, studies performed by the Indian Agricultural Research Institute (IARI) show that every 10 degrees Celsius increase in temperature may result in a loss of 4-5 million tons in annual wheat production (Kumar *et al*., 2024).In this context, Weather-Based Agro-Advisory Services (AAS) have emerged as a vital tool to support climate-resilient agriculture by providing timely, location-specific, and actionable weather and crop-related advisories to farmers. These advisories help farmers make informed decisions on sowing, irrigation, fertilisation, pest and disease management, and harvesting, thereby reducing losses and enhancing productivity and income (Rathore, 2013). Provision of accurate and locally-appropriate climate and weather information plays a vital building block in increasing the resilience of communities to climate change, diseases, and disasters (Manjunath et al., 2024; Srishailam et al., 2023).

Historically, farmers in India relied on indigenous weather knowledge and traditional practices to manage climatic risks (Gupta, 2004).While these practices offered resilience, they lacked the precision needed to cope with increasing weather variability and emerging challenges such as heat waves, cyclones, and erratic rainfall (Srishailam et al., 2023). Recognising this gap, scientific efforts to link meteorology with agriculture began in the early 20th century. The Royal Commission on Agriculture (1926) recommended closer collaboration between meteorologists and agricultural scientists to mitigate weather-induced crop losses and ensure food security (Agricultural Meteorology Division, IMD Pune, 1976).

This recommendation led to the establishment of the Agricultural Meteorology Division at the India Meteorological Department (IMD) in 1932, under the pioneering leadership of Dr. L.A. Ramdas. This was one of the earliest initiatives globally to systematically study the relationship between weather and crop performance (Agricultural Meteorology Division, IMD Pune, 2007). Early research focused on understanding soil moisture dynamics, evapotranspiration, and microclimate management, laying the foundation for science-based weather advisories.

Over subsequent decades, the agrometeorological framework in India evolved substantially. The launch of the Farmers' Weather Bulletin (FWB) in 1945 marked the first attempt to provide weather information directly to farmers. The introduction of Agrometeorological Advisory Services (AAS) in 1977 transformed simple forecasts into actionable farm management guidance. The establishment of the National Centre for Medium-Range Weather Forecasting (NCMRWF) in 1988 and the deployment of Agro-Meteorological Field Units (AMFUs) in 1991 advanced medium-range forecasting capabilities tailored to agro-climatic zones (Rathore *et al*., 2011; Bal et al., 2021).

The 21st century brought further integration and technological innovation. The Integrated Agrometeorological Advisory Services (IAAS), launched in 2008, merged parallel systems into a unified district-level framework supported by multi-model ensemble (MME) forecasting. In 2012, the Gramin Krishi Mausam Sewa (GKMS) scheme extended services to the block level through District Agro-Met Units (DAMUs) located at Krishi Vigyan Kendras, making advisories more localised and farmer-centric (Vijaya Kumar *et al*., 2017).If an accurate weather forecast is available, the farmer can lower the chance of failure by planning ahead and selecting crop cultivars, applying fertiliser at the right time, controlling weeds, pests, and diseases, and making the required preparations (Doss&Asokhan,2024).

Despite its rapid expansion and evident benefits, the effectiveness of AAS faces several challenges. These include issues of forecast accuracy at micro-levels, limited personalisation of advisories, inadequate last-mile connectivity, and gaps in farmer awareness and capacity to interpret and act on the information. Additionally, institutional and infrastructural constraints hinder the seamless integration of weather data with localised agronomic practices (Prabhakar *et al*., 2019).

Nevertheless, advancements in remote sensing, Artificial Intelligence (AI)-driven modelling, Information and Communication Technologies (ICTs), and participatory approaches are creating new opportunities to improve the reach, relevance, and responsiveness of AAS. Emerging models emphasiseco-production of advisories, integration with crop simulation tools, and feedback mechanisms to ensure user-centric design and delivery (WMO, 2019). This article presents a comprehensive review of the current challenges facing weather-based agro-advisory services in India and explores emerging opportunities for their enhancement in light of technological and institutional innovations.

2. EVOLUTION AND STRUCTURE OF AGRO-ADVISORY SERVICES IN INDIA

2.1 Early Foundations (1920s–1945)

The genesis of agrometeorological services can be traced to the Royal Commission on Agriculture (1926), which recognised the critical role of meteorology in improving crop production and reducing weather-induced losses. Responding to this recommendation, the India Meteorological Department (IMD) established the Agricultural Meteorology Division in 1932 at Pune under the leadership of Dr. L.A. Ramdas. This pioneering initiative marked one of the earliest global attempts to study weather–crop interactions scientifically (Agricultural Meteorology Division, IMD Pune, 1976; 2007).

During this formative stage, experimental observatories were set up on agricultural campuses to measure soil moisture, evapotranspiration, and microclimatic variables. Tools such as crop-weather diagrams and calendars were developed to guide planting, irrigation scheduling, and pest management. These efforts laid the foundation for systematic weather-based farm advisories.

2.2 Post-War Expansion: Farmers' Weather Bulletin (1945)

Following World War II, IMD redirected its resources toward civilian applications, leading to the launch of the Farmers' Weather Bulletin (FWB) in 1945. Broadcast via All India Radio, the FWB provided district-level weather forecasts, warnings for frost and storms, and rainfall outlooks crucial for sowing and harvesting (Agricultural Meteorology Division, IMD Pune, 2007). While innovative for its time, the FWB mainly delivered weather information without translating it into actionable agronomic advice. Farmers still had to interpret forecasts themselves, creating demand for more comprehensive advisory services.

2.3 State-Level Agromet Advisory Services (1977)

In 1976, the National Commission on Agriculture emphasised the need for weather-based farm management guidance. This led to the official launch of Agrometeorological Advisory Services (AAS) in 1977 from Madras (now Chennai) (NCA, 1976).

Using insights from the Satellite Instructional Television Experiment (SITE) of 1975–76, IMD began issuing biweekly advisories through radio and television, advising farmers on sowing windows, irrigation schedules, and crop protection measures. By the early 1980s, AAS had expanded to multiple states, marking India's first systematic attempt to integrate weather science with agricultural decision-making.

2.4 Medium-Range Forecasting and AMFUs (1991)

The severe droughts of the early 1980s underscored the need for medium-range forecasts (3–10 days) to support agricultural operations. Consequently, the National Centre for Medium-Range Weather Forecasting (NCMRWF) was established in 1988, introducing Numerical Weather Prediction (NWP) models to generate more accurate forecasts (Rathore, 2013).

In 1991, Agro-Meteorological Field Units (AMFUs) were set up across 127 agro-climatic zones, co-located with agricultural universities and the Indian Council of Agricultural Research (ICAR) research institutes. Agricultural scientists collaborated with meteorologists to interpret forecasts and prepare localised advisories. Feedback mechanisms and annual review meetings helped refine models and improve service delivery (Bal *et al*., 2021).

2.5 Integration and District-Level Services (2008)

By the early 2000s, AAS was operating under two parallel frameworks—IMD-led state advisories and NCMRWF-led agro-climatic zone advisories. To eliminate redundancy and improve efficiency, the Ministry of Earth Sciences convened a committee in 2006 to develop a unified system.

This led to the launch of Integrated Agrometeorological Advisory Services (IAAS) on 1 June 2008, providing district-level advisories. The system employed multi-model ensemble (MME) forecasting and leveraged SMS, print, and electronic media for dissemination. IAAS significantly expanded outreach, enabling millions of farmers to access actionable weather information (Recommendation Committee on IAAS, 2007; Rathore et al., 2011).

2.6 Gramin Krishi Mausam Sewa and Block-Level Advisories (2012–2018)

The success of IAAS revealed the need for even more granular forecasts. Recognizing variability within districts, the Gramin Krishi Mausam Sewa (GKMS) was introduced under the 12th Five-Year Plan (2012).

Under GKMS, District Agro-Met Units (DAMUs) were established in Krishi Vigyan Kendras (KVKs), staffed with trained agrometeorologists and observers. In 2018, block-level advisories were piloted in over 100 blocks, integrating high-resolution weather forecasts (12.5 km grids) with local field data. By 2023, block-level services expanded to cover approximately 3,100 blocks, ensuring hyper-local, actionable guidance for farmers (Vijaya Kumar et al., 2017).

The GKMS system provides five-day weather forecasts (covering rainfall, temperature, humidity, wind speed/direction, and cloud cover) and block-level advisories twice a week. These advisories are tailored for major crops, livestock, and fisheries and disseminated through SMS, mobile apps (e.g., *Meghdoot*, *Damini*), radio, TV, and social media platforms (IMD, 2023).

2.7 Modern Era: Advanced Technologies and Digital Outreach

Recent years have witnessed a shift toward digitally-enabled, demand-driven AAS. The adoption of ICTs, mobile phones, AI/ML-driven decision support systems, and GIS-based forecast models has transformed the scale and precision of advisories.

- **High-Resolution Models:** Introduction of GFS T1534 and ensemble-based probabilistic forecasts.
- **Automatic Weather Stations (AWS):** A network of over 200 Agro-AWS units captures real-time weather and soil data.
- **Satellite and Remote Sensing:** Used for estimating evapotranspiration, soil moisture, and crop health indices.
- **Digital Platforms:** Advisories are now disseminated via mobile apps, SMS, WhatsApp, and interactive voice systems.
- **FASAL** (Forecasting Agricultural Output using Space, Agrometeorology and Land-based observations),
- **Kisan Suvidha App** (launched by Ministry of Agriculture and Farmers Welfare (MoA&FW)),
- **Meghdoot App** (India Meteorological Department (IMD) + Indian Institute of Tropical Meteorology (IITM) collaboration),
- **Smart AAS platforms** by ICAR institutions and private agritech firms,

These innovations have made AAS more accurate, timely, and user-friendly, enhancingfarmers' ability to manage climatic risks. They have enabled more accurate, real-time, and crop-specific advisories at the village or even farm level (WMO, 2019). Furthermore, the introduction of climate-smart village models and participatory weather stations under projects like CCAFS (Climate Change, Agriculture and Food Security) has fostered two-way communicationand feedback loops between service providers and farmers.

2.8 Institutional Structure of AAS in India

India's AAS is a multi-tiered system involving diverse stakeholders:

Table 1. Institutional Structure of AAS in India

Level	Institution/Agency	Function
National	IMD, ICAR, IITM, ISRO	Forecast generation, modelling, national-scale advisories, satellite data
State/Regional	SAUs, ICAR KVKs, State Met Departments	District/block-level advisories, interpretation, training
District/Block	Agro-Met Field Units (AMFUs), KVKs	Localised advisory preparation, farmer interaction, feedback
Community	Farmer Producer Organisations, NGOs, Agri-startups	Dissemination, translation, personalisation, last-mile delivery

This collaborative approach ensures that scientifically generated forecasts are localised using indigenous knowledge and made accessible through multiple communication modes suited to varied literacy and connectivity levels.

3. CURRENT CHALLENGES

3.1 Accuracy and Resolution of Weather Forecasts

One of the most significant hurdles faced by AAS in India is the accuracy and spatial resolution of weather forecasts**.** WhileIMD (India Meteorological Department) provides weather information at the district and block levels, this often isn't enough to serve the unique needs of farmers who experience localised weather conditions that may vary drastically from one village to the next.

For example, a forecast for rainfall at the district level might miss a crucial detail—a sudden downpour that could damage crops in a specific locality but is not captured in the general forecast. This discrepancy is even more pronounced in regions with complex terrains like the Western Ghats or the Northeast. As a result, weather predictions, especially for short-term events like hailstorms or heatwaves, may fall short of expectations, leaving farmers unprepared (Chattopadhyay *et al*., 2016).

Moreover, while five-day forecasts are commonly used, they are still only 60-70% accurate for rainfall predictions at the district level. This is relatively low when considering the critical decisions that farmers must make, such as timing irrigation or applying fertilisers (IMD, 2023).

3.2 Generic and One-Size-Fits-All Advisories

Despite efforts to make advisories more localised, many of them remain overly general**,** focusing on widely grown crops and average weather conditions. These one-size-fits-all advisories often fail to address the specific needs of smallholder farmers who cultivate a variety of crops, manage mixed farming systems, or are dealing with unique micro-climatic conditions.

In India, farmers who grow vegetables**,** horticultural crops, or livestock often find that the advisory doesn't apply to their situation. The lack of personalised guidance also meansthat farmers with smaller landholdings or those using non-conventional farming methods may not benefit from the information provided.

For example, a rice farmer in West Bengal might need advice on water management tailored to his particular soil and crop variety, while a wheat farmer in Rajasthan would require guidance for managing heat stress during flowering. However, most AAS platforms continue to offer broad, crop-specific recommendations that don't address the nuances of local farming practices.

3.3 Connectivity Gaps and the Digital Divide

While digital tools like mobile apps and SMS-based advisories have expanded AAS access, last-mile connectivity remains a significant challenge, especially in rural and remote areas. In places where mobile coverage is patchy or unreliable, farmers may not receive timely advisories, leaving them unprepared for weather-related risks.

Additionally, there's a stark digital divide that limits the effectiveness of technology-driven solutions. Not all farmers have access to smartphones or the internet, and even among those who do, many lack the skills or literacy to navigate complex apps. Gender disparities in mobile phone ownership also complicate access, particularly in rural areas where women often take on primary agricultural responsibilities but are less likely to own or control mobile devices.

Even when farmers do receive messages, they may struggle to understand the technical language used in the advisories. As a result, farmers often ignore or misinterpret the messages, leading to low engagement and poor adoption rates.

3.4 Lack of Feedback and Interaction

Currently, India's AAS largely follows a top-down approach—experts generate advisories, and farmers receive them. There is limited opportunity for interaction, feedback, or co-creation of knowledge, which reduces the impact of these services.

In many cases, farmers receive weather and crop advisories without a clear understanding of how to adapt them to their specific situation. Without a feedback loop, it's difficult to know whether the advisories are effective or if they are actually being followed. For example, a farmer might receive advice to irrigate their fields, but they may not know the best timing based on their field's moisture level or the current temperature.

Farmers' local knowledge and field observations are often ignored in the advisory process. This lack of community participation hinders the development of more relevant, locally adapted advice (WMO, 2019).

3.5 Fragmented Institutional Framework

India's AAS system involves multiple institutions, from IMD and State Agricultural Universities (SAUs) to NGOs, private sector players, andfarmer organisations. This multi-tiered approach can sometimes lead to institutional fragmentation. Coordination issues between these stakeholders often result in duplication of efforts, alack of standardisation, and inefficiencies in resource allocation.

For instance, Agro-Met Field Units (AMFUs), responsible for providing localised advisories, are not always well-equipped with the latest technology or trained personnel. Some units lack the infrastructure to process and disseminate real-time data effectively. In addition, budget constraints and political influences can lead to uneven service quality across different states.

3.6 Climate Extremes and Forecast Limitations

India is witnessing an increasing frequency of extreme climate events—such as sudden floods, unseasonal rains, and heatwaves—which traditional weather forecasting models struggle to predict. For instance, compound events, where multiple extreme weather events occur in close succession, are becoming more common and are not always accounted for in standard forecasting models.

While early warning systems for extreme events like cyclones and droughts are well-established, their integration with agricultural advisories remains limited. For example, advisories for pest out breaks or heat stress on crops and livestock are often not linked with weather forecasts, leaving farmers ill-prepared for these secondary impacts (Rathore, 2013).

4. OPPORTUNITIES FOR STRENGTHENING AAS

4.1 Technological Innovations

Recent advancements in artificial intelligence (AI), machine learning (ML), big data analytics, and the Internet of Things (IoT) have immense potential to improve the precision and relevance of agro-advisories.

- AI-driven models can analyse real-time weather, soil, and crop data to generate

location-specific and crop-specific advisories.
- Satellite-based remote sensing and drone surveillance can enhance monitoring of crop phenology and pest outbreaks.
- Digital platforms can deliver personalised advisories via chatbots, mobile apps, or voice assistants in local languages.

4.2 Participatory and Demand-Driven Models

Engaging farmers in co-designing and validating advisory content can greatly enhance the credibility and adoption of AAS. Farmer Producer Organisations (FPOs), self-help groups (SHGs), and local NGOs can play a crucial role in feedback collection and content localisation.

4.3 Public-Private Partnerships (PPPs)

Private sector weather service providers like Skymet, IBM Weather Company, and CropIn offer high-resolution forecasts and customised farm advisory platforms. Collaboration with government agencies can scale innovation and ensure standardisation.

PPPs also provide opportunities for cost-sharing models, ensuring the financial sustainability of AAS beyond government funding.

4.4 Capacity Building and Institutional Reforms

- Training of field extension workers and AMFU staff in ICT tools, crop modelling, and communication strategies.
- Upgradation of KVKs and AMFUs with high-speed internet, automatic weather stations (AWS), and GIS tools.
- Clear delineation of responsibilities among IMD, ICAR, and SAUs with performance-based monitoring.

4.5 Integration with Climate-Smart Agriculture

Weather-based advisories should become part of broader climate-smart agriculturalstrategies, including risk insurance, contingency planning, and resilient cropping systems. The integration with State Action Plans on Climate Change (SAPCC) and District Agriculture Contingency Plans (DACP) can align efforts and funding.

5. RECENT POLICY SUPPORT AND INITIATIVES

5.1 National Innovation on Climate Resilient Agriculture (NICRA): Strengthening Agromet Policy Integration

The National Innovation on Climate Resilient Agriculture (NICRA) is a landmark initiative launched by the Indian Council of Agricultural Research (ICAR) in 2011 to address the challenges posed by climate variability and extreme weather events on Indian agriculture. Designed as a holistic climate adaptation program, NICRA offers vital policy and institutional support for climate-resilient practices, with a special focus on the development and dissemination of weather-based agro-advisories (AAS) (NICRA, 2020).

A core component of NICRA is the establishment of Climate-Smart Villages (CSVs), which serve as demonstration hubs for climate-resilient technologies, including location-specific AAS. These villages are equipped with automatic weather stations (AWS) and decision-support tools that help generate real-time advisories tailored to local agro-climatic conditions.

Key policy contributions of NICRA include:

- Climate vulnerability mapping at the district and block levels, enabling targeted development of agro-advisories for risk-prone areas (ICAR, 2022).
- Integration of AAS with district-level contingency crop plans, allowing farmers to modify cropping schedules, input use, and resource allocation in response to seasonal weather forecasts.
- Demonstration of weather-resilient agronomic practices through over 130 Krishi Vigyan Kendras(KVKs), including drought-tolerant crop varieties, water harvesting structures, and precision irrigation techniques.

5.2 Pradhan Mantri Fasal Bima Yojana (PMFBY): Convergence of AAS and Climate Risk Insurance

The Pradhan Mantri Fasal Bima Yojana (PMFBY), launched in 2016, is India’s flagship crop insurance scheme aimed at providing financial protection to farmers against crop loss

Table 2. Recent Policy Support and Initiatives in India

Policy Framework	Key Objectives	Integration with AAS	Institutional Mechanism	Reference
NICRA (National Innovation on Climate Resilient Agriculture)	Build resilience in agriculture through climate-smart technologies and practices	• Climate vulnerability mapping for location-specific AAS • AAS integrated with contingency crop planning • Weather-resilient demonstrations via KVKs and Climate-Smart Villages	Led by ICAR; implemented via KVKs, supported by AWS and ICT tools	ICAR (2022). NICRA Annual Report https://www.nicra-icar.in
PMFBY (PradhanMantriFasalBimaYojana)	Provide crop insurance against weather-induced losses	• AAS supports trigger mechanisms in claim processing • Monitoring drought and post-harvest loss using weather data • GPS-tagged advisories aid risk mitigation and transparency	Led by MoA&FW; implemented through State Departments, insurers, and tech platforms (e.g., Crop Insurance App)	MoA&FW(2023). PMFBY Guidelines 2.0 https://pmfby.gov.in
Digital Agriculture Mission (DAM)	Leverage digital technologies (AI, IoT, big data) for modernizing agriculture	• Creation of federated farmer databases linked to weather records • Open APIs for weather and DSS platforms • PPPs with AgTechs for delivering customized digital AAS	Led by MoA&FW; partnered with tech firms (e.g., Microsoft, AWS), ICAR, and States	MoA&FW(2021). Digital Agriculture Mission Strategy https://agricoop.gov.in
NeGPA(National e-Governance Plan in Agriculture)	Enable digital service delivery in agriculture through ICT infrastructure	• Support for DSS integrating AAS with other advisory services • Development of mobile platforms (e.g., Meghdoot, Kisan Suvidha) • State-level customization of AAS in local languages	Funded by MoA&FW; implemented by State Agriculture Departments, supported by NIC, CDAC	MoA&FW (2023). NeGPA Phase II Report https://agricoop.gov.in

due to natural calamities and weather extremes. One of the evolving strengths of PMFBY lies in its increasing reliance on weather-based agrometeorological data and advisories to improve risk assessment and expedite claim processing.

With the use of remote sensing technologies, automated weather stations (AWS), and satellite imagery, PMFBY now actively incorporates AAS into multiple stages of the insurance cycle. Key areas of integration include:

- Trigger mechanisms for insurance payouts based on pre-defined weather thresholds such as rainfall deviation, temperature extremes, or soil moisture deficits. AAS plays a key role in flagging anomalies early, enabling quicker response.
- Monitoring of post-harvest losses and drought progression using real-time weather data combined with GIS and agromet advisories, particularly in regions prone to late-season weather shocks.
- Deployment of GPS-tagged AAS and mobile platforms to deliver risk mitigation strategies and claim-related information directly to farmers.

Recent policy guidelines under PMFBY 2.0 emphasise the convergence of crop insurance with digital weather services to improve transparency, reduce claim disputes, and enhance farmer trust in the system (Ministry of Agriculture, 2023). The introduction of the Crop Insurance App, integration with the Meghdoot weather advisory system, and collaboration with private weather agencies further strengthen this linkage

6. CONCLUSION

Weather-based agro-advisory services are pivotal in helping Indian farmers adapt to climate variability and make timely agricultural decisions. While the system has expanded in scope and coverage, substantial gaps in accuracy, personalisation, accessibility, and institutional capacity need to be addressed. By leveraging emerging technologies, enhancing stakeholder coordination, and fostering participatory approaches, AAS in India can evolve into a robust support system for sustainable and climate-resilient agriculture.While weather-based agro-advisory services have certainly made strides in India, they still face significant challenges that hinder their potential to support farmers effectively. The key to overcoming these hurdles lies in improving forecast accuracy**,** personalising advisories, enhancing last-mile connectivity, and fostering institutional collaboration. If these issues are addressed, AAS can play a transformative role in supporting farmers' resilience to the growing threats of climate change.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Agricultural Meteorology Division. (1976). *Chapter 15: Service to Agriculture*. In *Hundred Years of Weather Services (1875–1975)* (pp. 174–184). India Meteorological Department.

Agricultural Meteorology Division. (2007). *A Retrospective and Futuristic Overview: 75 Years Service to the Nation*. Agricultural Meteorology Division, IMD Pune.

Bal, S. K., Rao, K. V., Chandran, M. A. S., Sasmal, S., & Singh, V. K. (2021). Weather forecast, agriculture contingency plan and agromet-advisory services for climate resilient agriculture. *Indian Journal of Agronomy, 66*(5th IAC Special issue), S1–S14.

Bal, S. K., Rao, K. V., Chandran, M. S., Sasmal, S. U. B. O. D. H., & Singh, V. K. (2021). Weather forecast, agriculture contingency plan and agromet–advisory services for climate resilient agriculture. *Indian Journal of Agronomy, 66*, S1–S14.

Chattopadhyay, N., Ghosh, K., & Chandras, S. (2016). Agrometeorological advisory to assist the farmers in meeting the challenges of extreme weather events. *Mausam, 67*(1), 277–288.

Doss, D. A., &Asokhan, M. (2024). Awareness on weather based agro-advisory services among farmers of Tamil Nadu, India. *International Journal of Environment and Climate Change, 14*(3), 177–182.

Gupta, A. K. (2004). Origin of agriculture and domestication of plants and animals linked to early Holocene climate amelioration. *Current Science, 87*(1), 54–59.

ICAR. (2022). *NICRA Annual Report 2021–22*. Indian Council of Agricultural Research, New Delhi. https://www.nicra-icar.in

IMD (India Meteorological Department). (2023). *Gramin Krishi Mausam Sewa (GKMS)*. https://mausam.imd.gov.in/

Kumar, V. P. Y., Singh, A. K., Jeet, P., Ahmed, A., Saurabh, K., Kumari, A., ... & Das, A. (2024). Advancing sustainable crop production through agro-advisory services: A review. *Journal of AgriSearch, 11*(4), 234–241.

Manjunath, K. V., Maiti, S., Garai, S., Reddy, D. A. K., Sahani, S., Panja, A., & Jha, S. K. (2024). Impact of climate services on the operational decision and economic outcome of wheat (*Triticum aestivum*) and rice (*Oryza sativa*) cultivation in Haryana. *Indian Journal of Agricultural Sciences, 94*(3-S1), 116–123.

MoA&FW. (2021). *Digital Agriculture Mission Strategy Document*. https://agricoop.gov.in

MoA&FW. (2023). *PMFBY Operational Guidelines Version 2.0*. Government of India. https://pmfby.gov.in

National Commission on Agriculture (NCA). (1976). *Report of the National Commission on Agriculture*. Ministry of Agriculture, Government of India.

NICRA. (2020). *Annual Report*. National Innovations in Climate Resilient Agriculture, ICAR.

Prabhakar, S. V. R. K., & Shaw, R. (2019). Globalization of local risks through international investments and businesses: A case for risk communication and climate fragility reduction. *Contributing Paper to GAR 2019*.

Rathore, L. S. (2013). Weather information for sustainable agriculture in India. *Journal of Agricultural Physics, 13*(2).

Rathore, L. S., Chattopadhyay, N., & Singh, K. K. (2011). *Agrometeorological services for farmers in India*. WMO Technical Note.

Recommendation Committee on IAAS. (2007). *Report on Integrated Agrometeorological Advisory Services*. Ministry of Earth Sciences, Government of India.

Srishailam, B. V., Sailaja, P., Ganesh Kumar, D., & Subramanyam, S. N. U. (2023). Index to assess the impact of weather based agro-advisory services among the cotton growers of Telangana and Andhra Pradesh States. *Biological Forum – An International Journal, 15*(4), 740–746.

Vijaya Kumar, P., Subba Rao, A. V. M., Chandran, M. A. S., Venkatesh, H., Rao, V. U. M., & Srinivasarao, Ch. (2017). Micro-level agromet advisory services using block level weather forecast – a new concept-based approach. *Current Science, 112*, 227–228.

WMO (World Meteorological Organization). (2019). *Guidelines on providing forecast-based and early warning services to agriculture*. Geneva: WMO.

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