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# ADVANCEMENTS IN AGRICULTURAL TECHNOLOGY: HARNESSING WEATHER DATA AND AGRO-METEOROLOGICAL INSIGHTS FOR ENHANCED FARM MANAGEMENT AND SUSTAINABILITY

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**Abstract:** *This research paper explores the critical role of weather forecasting in agriculture and its integration with agricultural meteorological data to facilitate informed decision-making, risk mitigation, and agricultural planning. It emphasizes the significance of agricultural meteorological data, including temperature, precipitation, humidity, wind speed, solar radiation, and soil moisture content, collected from strategically positioned meteorological stations. The paper advocates for a dynamic weather advisory framework that adopts a multi-hazard approach, provides sector-specific advisories, ensures geographical specificity, and emphasizes effective communication channels. Highlighting Indian government agricultural initiatives with AGROMET integration, the paper underscores their importance in modernizing agriculture, enhancing resilience, and promoting sustainable practices. In conclusion, it emphasizes the pivotal role of weather forecasting in agriculture, contributing to enhanced farm productivity, resilience, and sustainability amidst changing climatic conditions.*

**Key words:** Weather forecasting, Meteorological Data, Weather Advisory, AGROMET

## Introduction

India boasts some of the world's oldest meteorological observatories, with the first astronomical and meteorological units commencing operations in Madras in 1793. This indicates that meteorological observations in India predate the establishment of the official department in 1875. Since its inception, the Indian Meteorological Department (IMD) has reached numerous milestones, marking significant progress in the field from 1793 to 2022. In 2009, the concept of climate-smart agricultural development emerged to tackle the intricate task of harmonizing worldwide agricultural output with the imperative of enhancing the durability of agricultural systems in response to climate change impacts. Simultaneously, it aimed to curb greenhouse gas (GHG) emissions arising from agricultural practices. This approach aimed to navigate the multifaceted challenges associated with maximizing agricultural productivity, ensuring agricultural system resilience in the context of climate change, and mitigating GHG emissions from agricultural activities. A year later, at the First Global Conference on Agriculture, Food Security, and Climate Change in The Hague, the concept of climate-smart agriculture (CSA) was formally introduced. CSA was defined as an approach to agriculture that seeks to increase productivity in a sustainable manner, strengthen the capacity of agricultural systems to withstand the impacts of climate change, reduce or eliminate GHG emissions associated with agricultural practices, and contribute to the attainment of national food security and development objectives. In essence, CSA embodies a comprehensive strategy that integrates sustainable productivity, resilience building, emission reduction, and developmental goals within agricultural practices (Jaybhaye et al., 2018). In order to provide food security, reduce poverty, and protect the essential natural resource that the current and future generations of people on the planet will be totally dependent upon for their life and well-being, agriculture is absolutely essential (Dhakal, 2019). Weather stands as a pivotal determinant for the success or failure of agricultural endeavours, impacting every facet of plant growth and development. Variability in weather conditions throughout the crop season, such as monsoon delays, excessive rainfall, floods, droughts, and extreme temperatures, significantly influences crop growth and ultimately affects both the quality and quantity of yield. Effective utilization of weather forecasts and agro-advisory services plays a pivotal role in mitigating climatic risks associated with wheat production. By leveraging weather forecasts and agro-advisory bulletins, farmers can make informed short-term decisions regarding irrigation scheduling, pesticide application, and other agronomic practices, thereby minimizing the wastage of expensive inputs and enhancing crop productivity. The primary objective of weather forecasting is to provide farmers with insights into current and anticipated weather conditions, enabling informed decision-making in day-to-day farming operations such as sowing, weeding, pesticide application timing, irrigation scheduling, and fertilizer application. Weather forecasts contribute to increased agricultural production, improved water use efficiency, reduced input costs (including labor and energy), minimized losses and risks, decreased pollution, and enhanced yield quality through prudent management practices. Consequently, the application of agrometeorological advisory bulletins, grounded in current and projected weather data, emerges as a valuable tool for augmenting agricultural production and income.

## Importance of Agricultural Meteorological Information in Farming

Weather forecasting plays a critical role in agriculture, serving as a valuable tool for farmers, agronomists, and agricultural policymakers worldwide. Agricultural meteorological data encompasses a comprehensive set of meteorological parameters specifically relevant to agricultural activities, including but not limited to temperature, precipitation, humidity, wind speed and direction, solar radiation, and soil moisture content (Sultan et al., 2013), (Gourdji et al., 2013). The significance of agricultural meteorological data lies in its pivotal role in informing agricultural decision-making processes and optimizing farming practices (Azzam et al., 2016). These data are collected and analyzed from meteorological stations strategically positioned within or near agricultural regions (Lobell & Field, 2007). By providing insights into prevailing weather conditions and their potential impact on crops, soil, and overall farm operations, agricultural meteorological data enables farmers to make informed decisions regarding planting schedules, irrigation management, pest and disease control, harvesting operations, and resource allocation (Han et al., 2018), (Antwi-Agyei et al., 2019). This data-driven approach helps farmers mitigate risks associated with adverse weather events, optimize resource use efficiency, minimize crop losses, and ultimately enhance farm productivity and sustainability (Li et al., 2019; Mu et al., 2020; Raza et al., 2021; Wang et al., 2021). The ability to accurately predict weather conditions enables stakeholders to make informed decisions about crop management, irrigation scheduling, pest control, and harvesting operations.

**Dynamic Weather Advisory Framework**

1. **Multi-Hazard Approach**: The importance of adopting a multi-hazard approach in weather advisories to address various meteorological phenomena and their potential impacts on different sectors Yarnal, (2003). This approach ensures comprehensive preparedness and resilience to a wide range of weather-related hazards.
2. **Sector-Specific Advisories**: Sector-specific weather advisories provide tailored guidance for different sectors, enabling stakeholders to make informed decisions and take appropriate actions based on their specific vulnerabilities and needs. This targeted approach enhances the effectiveness of weather advisory systems in supporting sectoral resilience.
3. **Geographical Specificity**: The importance of geographical specificity in weather forecasting and advisories, particularly in regions with complex terrain and microclimates. Tailoring advisories to specific geographical regions ensures accuracy and relevance, enhancing their utility for local stakeholders.
4. **Temporal Relevance**: By emphasize the temporal relevance of weather forecasts and advisories, particularly in the context of extreme weather events and seasonal variations Robertson et al., (2020). Timely and accurate advisories enable stakeholders to prepare for imminent weather hazards and plan for long-term climate variability, contributing to enhanced resilience.
5. **Communication Channels**: Explores various communication channels for disseminating weather information, including traditional media, social media, mobile applications, and community-based approaches Katz et al., (2019). Effective communication channels play a crucial role in ensuring the accessibility and usability of weather advisories for diverse stakeholders.
6. **Language and Cultural Sensitivity**: By emphasize the importance of language and cultural sensitivity in weather communication and advisories Dilling et al., (2015). Providing information in local languages and formats that resonate with the cultural context enhances the effectiveness and uptake of advisories among target populations.

**Indian Government Agricultural Initiatives with AGROMET Integration**

1. **Agriculture - Mission Mode Project (A - MMP):** The Agriculture - Mission Mode Project (A - MMP) aims to modernize agriculture through the use of information technology. It includes initiatives to improve agricultural practices, market access, and farmer welfare through the adoption of digital technologies and data-driven approaches.

2. **National Agricultural Drought Assessment and Monitoring System (NADAMS):** NADAMS is a government initiative focused on assessing and monitoring agricultural drought conditions in India. It utilizes meteorological data, remote sensing, and other tools to provide timely information on drought severity and its impact on agriculture.
3. **Weather-Based Crop Insurance Scheme (WBCIS):** The Weather-Based Crop Insurance Scheme (WBCIS) is a government-sponsored crop insurance program that uses weather parameters such as rainfall, temperature, and humidity to determine insurance payouts. It aims to protect farmers from crop losses caused by adverse weather conditions.
4. **Kisan Suvidha Mobile App:** The Kisan Suvidha mobile app is developed by the Indian government to provide farmers with access to agricultural information and services. It includes features such as weather forecasts, market prices, agricultural advisories, and information on government schemes and programs.
5. **Mausam App:** The Mausam mobile app is developed by the India Meteorological Department (IMD) to provide weather forecasts and advisories to the general public, including farmers. It offers location-specific weather information, including temperature, rainfall, humidity, and wind speed.
6. **National Innovations on Climate Resilient Agriculture (NICRA):** NICRA is an initiative launched by the Indian Council of Agricultural Research (ICAR) to address climate change challenges in agriculture. It focuses on developing climate-resilient agricultural practices and technologies to enhance productivity and sustainability.
7. **Agro-Meteorological Advisory Services (AAS):** AAS is a government program that provides location-specific weather forecasts and advisories to farmers. It aims to help farmers make informed decisions regarding crop management practices based on weather forecasts and agro-meteorological information.
8. **National e-Governance Plan for Agriculture (NeGP):** NeGP for Agriculture aims to leverage information and communication technologies (ICT) to improve agricultural governance and service delivery. It includes initiatives to digitize agricultural data, enhance farmer access to information and services, and improve agricultural productivity.
9. **Rashtriya Krishi Vikas Yojana (RKVY):** RKVY is a state-sponsored scheme aimed at enhancing agricultural productivity and promoting agripreneurship. It supports various agricultural development projects and initiatives at the state level to boost agricultural growth and rural livelihoods.
10. **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY):** PMKSY is a government scheme focused on enhancing water use efficiency in agriculture through various interventions such as efficient irrigation practices, water conservation, and water management infrastructure development.
11. **National Mission for Sustainable Agriculture (NMSA):** NMSA is a government mission aimed at promoting sustainable agriculture practices that enhance productivity, resilience, and adaptability to climate change. It includes initiatives to promote climate-smart agriculture, soil health management, and water conservation in agriculture.

**Models of AGROMET in India:**

**GFS (Global Forecast System):**

- Developed by NCEP.
- Provides forecasts for various weather variables globally.
- Utilized for agricultural practices due to its comprehensive coverage and high spatial and temporal resolution.

**GEFS (Global Ensemble Forecast System):**

- Ensemble version of GFS.
- Generates multiple forecasts to account for uncertainties in initial conditions.
- Helps in assessing forecast confidence and uncertainty.

**WRF (Weather Research and Forecasting Model):**

- High-resolution regional model.
- Used for detailed forecasts in specific geographic areas.
- Particularly useful for localized agricultural planning and management.

**HWRF (Hurricane Weather Research and Forecasting Model):**

- Specialized model for tropical cyclones and hurricanes.
- Provides detailed forecasts of wind, rainfall, and storm surge.
- Important for agricultural regions vulnerable to hurricanes.

**HRRR (High-Resolution Rapid Refresh Model):**

- Short-range forecasting model.
- Offers high-resolution forecasts updated frequently (hourly).
- Beneficial for making real-time decisions in agriculture.

**ERF (Extended Range Forecast):**

- Model for long-range forecasts beyond the typical forecast period.
- Helps in planning agricultural activities weeks or months in advance.
- Useful for seasonal crop planning and climate risk assessment.

**MME (Multi-Model Ensemble):**

- Integration of multiple forecast models.
- Averages predictions from different models to improve forecast accuracy.
- Enhances reliability of forecasts, especially for critical agricultural decisions.

**UM (Unified Model):**

- Developed by the UK Met Office.
- Highly versatile model used for weather and climate prediction.
- Offers high-resolution forecasts for various weather variables.

**GSM (Global Spectral Model):**

- Developed by the National Centres for Environmental Prediction (NCEP) in the US.
- Utilizes spectral techniques for global weather prediction.
- Provides forecasts for a wide range of meteorological parameters.

## Conclusion

Without intervention to address trends in human diet and food waste within food systems, the demand for food production would soar by approximately 70% by 2050 to accommodate an estimated global population of 9 billion people. This surge would have profound environmental and societal impacts. Recent spikes in food prices have underscored the clear connections between political and economic stability and food security. Consequently, agricultural development is now receiving renewed emphasis in both research and policy circles (Jaybhaye et al., 2018). The Agromet Advisory Services, located within the Agricultural Physics Division of the Indian Agricultural Research Institute (IARI) in New Delhi, has been actively assisting farmers in the National Capital Region (NCR) and its surrounding areas. Progressive farmers have shown a strong interest in these agro-advisories, benefiting significantly from them. The primary aim of this program is to offer timely and tailored advice on crop management practices according to the prevailing conditions. Weather forecasts, covering parameters like rainfall, maximum and minimum temperatures, wind speed and direction, cloud cover, and humidity levels, are received from the Indian Meteorological

Department (IMD), New Delhi, every Tuesday and Friday. Upon receiving these forecasts, inputs are sought from experts across different fields. Based on their recommendations, agro-advisories are crafted and disseminated in both Hindi and English every Tuesday and Friday. These advisories are shared with IMD to compile national bulletins and are made available on the IMD website in both languages. Farmers receive these bulletins in real-time via telephone, email, or SMS. Additionally, they are emailed to local Hindi newspapers for publication and uploaded on the IARI website in both languages. Furthermore, these bulletins are distributed to various organizations and platforms through email, including ATIC, KVK Shikohpur, KVK Ujawa, IKSL, NGO, ATMA, State Agriculture departments, e-choupal, Krishi Darsan, and All India Radio. The agro-advisory bulletins, based on weather forecasts, encompass summaries of the previous week's weather, deviations from normal weather patterns, forecasts for the upcoming five days, and crop management recommendations aligned with the forecasted weather conditions. They also include advance warnings to farmers about anticipated rainfall variations, amounts, and other weather-related variables such as pest and disease issues. Consequently, farmers can make informed decisions regarding crop management practices, nutrient application, and strategies to address various agricultural challenges (Vashisth et al., 2013). Utilizing weather forecasts and agromet advisories aids farmers in maximizing economic gains by recommending appropriate management strategies tailored to prevailing weather conditions.

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