

Significance of Weather Forecasting in Crop Production with respect to Indian Scenario

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ABSTRACT

Weather significantly impacts agricultural production by influencing crop growth, development, and yields, as well as the occurrence of pests and diseases. It also affects water requirements and nutrient mobilization under varying moisture conditions, and it determines the timing and efficacy of preventive and cultural practices in crop management. There are total of five types of weather forecasting which includes short range forecast, extended forecast, long range forecast, now casting and climatological forecasting. Several factors like cloud cover (quantity and variety), temperature, direction and speed of the wind, snowfall and rain, relative moisture content, extreme weather conditions, such as waves of heat or cold, fog, frost, hail, thunderstorms, low-pressure zones, wind squalls and gales, and varying degrees of depressions, cyclones, and tornadoes are considered while forecasting. As the world grapples with global warming and climate change, which have devastating effects on global food production, the significance of weather forecasting in agriculture becomes increasingly crucial to be considered for ensuring food safety and profitability of farmers.

INTRODUCTION

India, predominantly an agricultural nation, continues to rely heavily on its farming sector despite the growth of tertiary industries. The meteorological conditions in any region or locality significantly influence

the success or failure of crop production across different stages of plant growth and development. Weather variability, including factors like delayed monsoons, excessive rainfall, droughts, floods, heat waves, and cold

spells during the crop cycle, directly impacts crop growth, as well as the quality and quantity of overall crop yields. Weather conditions play a critical role in agriculture, and precise forecasts can profoundly impact crop yields, resource management, and the overall profitability of farms (Sarma *et al.*, 2024). Accurate weather forecasts play a crucial role in enhancing agricultural productivity by mitigating risks and losses, optimizing resource utilization such as nutrients and water, and ultimately contributing to sustainable agricultural practices. The Indian Meteorological Department (IMD), headquartered in Pune, produces advance weather forecasts for India, which are disseminated through mass media such as radio, television, and newspapers. Weather forecasting is the scientific and technological prediction of atmospheric conditions for specific locations and times. It relies on understanding both the typical and seasonal weather patterns of an area, as well as precise current weather data encompassing all relevant meteorological elements at the time of forecasting.

Types of weather forecasting:

There are five types of weather forecasting which are as follows:

1. Short range forecast

Short-range weather forecasts are daily predictions based on current weather data, focusing primarily on pressure, temperature changes, and cyclonic tendencies. These forecasts are crucial for Irrigation Engineers, Mariners, and aviators as they provide timely alerts and precautions during storms, cyclones, heavy rains, etc. They also aid in preparing pre-emptive measures such as constructing embankments and drains to mitigate potential flood and storm damage. Typically, valid for 24 to 48 hours, these forecasts boast an accuracy ranging from 70% to 80%. It helps in

determining irrigation schedules, timing agricultural operations, and safeguarding plants from frost.

2. Extended forecast

This type of forecast focuses on specific weather conditions, including the pattern of rainy days and common agricultural risks such as strong winds, prolonged dry or wet periods. It remains reliable for 5 to 7 days, typically achieving an accuracy level of 60% to 70%. This forecast is particularly valuable for various agricultural activities like sowing and spraying, providing farmers with essential information to plan and execute their operations effectively. These forecasts are instrumental in determining optimal sowing times, assessing the appropriate depth for sowing, scheduling harvesting activities, and determining the ideal timing for spraying pesticides and applying foliar nutrition. They also aid in overall farm management by providing critical information that farmers can use to plan their operations efficiently and maximize crop yields.

3. Long range forecast

Long-range seasonal forecasts, covering the next 1-2 months, are valuable for anticipating climate trends and adjusting cropping strategies accordingly. They aid in managing soil moisture, selecting appropriate crops, making decisions on irrigation management under water scarcity, and planning cropping patterns effectively. These forecasts provide essential guidance for agricultural planning, ensuring farmers can adapt to expected weather conditions and optimize their crop production strategies.

4. Now casting

Such weather forecasting provides predictions typically 2 to 3 hours ahead, benefiting aviation and navigation sectors. Additionally, "nowcasting," which utilizes radar and satellite

data, forecasts conditions up to 6 hours in advance. This method is particularly adept at predicting short-term weather phenomena such as lightning.

5. Climatological forecasting

Climatological forecasts involve predicting long-term climate variables like temperature, precipitation, and sea level over periods ranging from several decades to centuries. These forecasts rely on climate models that simulate interactions among Earth's atmosphere, oceans, land surfaces, and ice, including the effects of human activities such as greenhouse gas emissions.

Types of observations

The data collected for forecasting are generally based on following observations:

1. Surface observations

2. Upper air observations

3. Aircraft observations

4. Radar observations

5. Satellite observations

The data collected from various sources is transmitted to meteorological centers for analysis, where it is processed to create a range of charts, maps, and graphs. Advanced high-speed computers are used to integrate thousands of observations into both surface and upper-air maps efficiently.

Factors to be considered for agricultural weather forecasts

An agricultural weather forecast should include all relevant weather elements that directly impact farm planning and operations. These elements vary depending on location and change with each season. A weather forecast usually comprises the following information: cloud cover (quantity and

variety), temperature (highest, lowest, and dew point values), direction and speed of the wind, snowfall and rain, relative moisture content, extreme weather conditions, such as waves of heat or cold, fog, frost, hail, thunderstorms, low-pressure zones, wind squalls and gales, and varying degrees of depressions, cyclones, and tornadoes (Prakash *et al.*,2022). The weather has an impact on every aspect of agricultural operations. However, the types of crops, their growth stages, and the weather requirements for the best crop development, yield, and incidence of pests and diseases, as well as the susceptibility of various crops to weather-induced stressors and pest and disease afflictions, differ. Crops and cropping techniques must be chosen so that the crop's temporal march coincides with the cardinal phased weather requirements for maximum productivity at a particular location. All measured parameters can be applied to particular field operations, including crop protection and fertilisation schedules, pest warning systems, and irrigation schedules. Using weather data in farming is essential to effective farm management. More significantly, it guarantees environmentally friendly farming, preserving the environment

Methodology of weather forecasting

The weather forecasting process involves several key steps, including observations, data analysis, numerical modelling, and communication which are mentioned as follows:

- 1. Collection of Data:** Meteorologists gather data from diverse sources to monitor present atmospheric conditions. This includes data on temperature, humidity, air pressure, wind speed and direction, cloud cover, and precipitation. Sources range from satellites and weather stations to buoys, radar systems, and weather balloons.

2. **Proper observation and Analysis:** The collected data undergoes thorough examination and analysis by meteorologists to understand the current atmospheric state. They scrutinize patterns and trends in the data to interpret weather phenomena such as temperature fluctuations, pressure systems, and wind behaviours.
3. **Use of Numerical Weather Prediction (NWP) model:** Meteorologists utilize advanced computer models known as Numerical Weather Prediction (NWP) models to forecast upcoming weather conditions. These models simulate atmospheric dynamics using complex mathematical equations rooted in principles of physics and fluid dynamics.
4. **Initialisation of model:** The process begins with NWP models being initialized using current observational data, establishing a starting point for predicting how the atmosphere will evolve.
5. **Integration of model:** Following initialization, the models undergo extensive calculations to simulate complex interactions within the atmosphere. The atmosphere is divided into a grid, with equations solved for each grid point to simulate processes such as temperature fluctuations, air circulation, moisture transport, and cloud formation.
6. **Generation of forecast:** NWP models produce forecasts for various weather parameters, including temperature, precipitation, wind speed and direction, and cloud cover. These forecasts span different time frames, from short-term predictions covering a few hours to longer-term forecasts spanning several days or weeks.
7. **Verification and adjustment:** Meteorologists assess the accuracy of model forecasts by comparing them with observed weather conditions. Any discrepancies are noted, and adjustments may be made to the forecasts based on expert analysis and additional data validation.
8. **Interpretation and Communication:** Meteorologists analyze forecast data considering local geography, climate nuances, and prevailing weather patterns. Their expertise enables them to generate tailored weather forecasts and alerts specific to different regions and audiences. These forecasts are communicated through diverse channels such as television, radio, websites, mobile apps, and social media platforms.
9. **Dissemination of information:** Weather forecasts are distributed to the public and sectors like agriculture, aviation, and emergency services, aiding informed decision-making. Accurate and timely weather information is crucial for planning activities, mitigating risks, and ensuring public safety.
10. **Continuous monitoring and feedback:** Meteorologists maintain ongoing vigilance over evolving weather conditions, continually updating forecasts as new data is gathered. This active monitoring allows for real-time adjustments to forecasts, ensuring the public receives the latest information needed to make informed decisions.

Methods used in forecasting are as follows:

1. **Climatological approach:** The climatology method relies on weather statistics compiled over many years to generate forecasts. Meteorologists apply this technique by averaging historical

weather data and predicting future conditions based on past patterns for the same day and location. This method is effective when weather patterns are stable. However, in dynamic environments where external factors such as climate change influence weather unpredictably, the climatology method may not yield accurate forecasts.

2. **Analog method:** The analog method presents challenges in weather prediction because it involves identifying a historical day with weather conditions similar to the current forecast, which can be complex. For instance, if today's forecast predicts a warm day followed by a cold front moving into the area, the forecaster might recall a similar day in the recent past when such conditions led to thunderstorm development later on. Using this analogy, the forecaster may predict a similar outcome for today's weather. However, even minor differences between past and present conditions can alter the forecast, highlighting the limitations of the analog method in accurately predicting weather outcomes.
3. **Persistence and Trends Method:** The persistence and trends method is a straightforward approach to weather prediction as it relies solely on historical trends. Ideally, in a stable atmospheric environment, tomorrow's forecast would mirror today's, with adjustments made according to seasonal norms. This method involves monitoring current temperatures and conditions while referencing the region's typical climate averages.
4. **Numerical weather prediction modelling:** Numerical Weather Prediction (NWP) modelling stands as the predominant and highly precise approach in weather forecasting. It revolves around

solving complex mathematical equations that encapsulate the fundamental physical laws governing atmospheric processes. Utilizing extensive observational data, NWP models replicate atmospheric dynamics, enabling meteorologists to produce comprehensive forecasts for diverse weather parameters.

Importance of weather forecasting in agricultural system

Weather conditions at specific locations are subject to continuous changes over time, with variability not only across different time periods but also across geographical areas. These variations in weather can lead to various impacts such as reduced crop performance, physical damage to crops, soil erosion, and decreased effectiveness of agricultural inputs. The quality of crop produce during storage and transportation is also heavily influenced by weather conditions, which can deteriorate if exposed to adverse weather. Farmers rely on this data to monitor and adjust irrigation schedules, apply fertilizers, and manage pest control effectively. Understanding soil moisture levels and evapotranspiration helps farmers determine the optimal amount of water needed for crops, with adjustments made based on current weather conditions. Fertilizer application timing is also guided by weather patterns; heavy rainfall may necessitate reapplication due to nutrient leaching, whereas dry spells might require more frequent applications to maintain soil fertility. Moreover, weather data aids farmers in predicting and controlling pest outbreaks. Specific pests thrive under particular temperature and moisture conditions, following seasonal patterns that affect their breeding and growth cycles. For instance, monitoring Growing Degree Days (GDD) helps predict pest activity. Proper timing of pest control measures is crucial for

minimizing crop damage and maximizing yields during harvest season.

This data is also crucial to safeguard livestock from temperature extremes. Monitoring key factors like temperature and soil moisture levels throughout the growing season helps determine optimal conditions for crop growth and harvest. By tracking temperature trends, farmers can predict crop maturity and select the optimal time for harvesting, ensuring higher quality produce with extended shelf life. Furthermore, weather data plays a pivotal role in planning post-harvest activities such as drying and curing. Air moisture levels and temperature variations influence the quality of the final agricultural products. Farmers use this information to schedule these activities effectively, enhancing the overall quality and marketability of their crops.

While efforts are made to synchronize agricultural activities with favourable weather conditions, predicting weather patterns accurately every year is challenging. Therefore, forecasts covering different weather parameters are crucial to allow proactive measures to mitigate the effects of unfavourable weather conditions. Weather forecasts also enable farmers to optimize agricultural practices by adjusting cropping patterns, field operations, and input schedules based on expected weather conditions. Although agronomic strategies are available to cope with changing weather, once the cropping season begins, adjustments must rely on early warnings of mid-season weather hazards. The demand for timely and precise weather forecasts among farmers has risen significantly with the advancement and accessibility of information technology in rural areas.

Role of India Meteorological Department (IMD)

The India Meteorological Department (IMD) operates the Gramin Krishi Mausam Sewa (GKMS) scheme to provide essential agrometeorological advisory services to the farming community nationwide. Through this initiative, medium-range weather forecasts are generated for districts and blocks. Based on these forecasts, 130 Agromet Field Units (AMFUs), situated at various State Agricultural Universities, ICAR institutes, and IITs, prepare tailored advisories every Tuesday and Friday. These advisories are aimed at assisting farmers in making informed decisions regarding their day-to-day agricultural activities. The IMD's AAS initiative focuses on implementing weather-dependent strategies for crop and livestock management, ultimately aiming to boost agricultural productivity, ensure food security, and mitigate losses caused by adverse weather conditions. Following the successful implementation of district-level Agrometeorological Advisory Services (AAS), District Agromet Units (DAMUs) are now being established at Krishi Vigyan Kendras (KVKs) in collaboration with ICAR to extend advisory coverage to the block level. Currently, 199 DAMUs have been set up at KVKs nationwide under the ICAR network. These units prepare Agrometeorological Advisories for both district and block levels based on respective weather forecasts every Tuesday and Friday. Additionally, they also formulate Impact-based Forecasts (IBFs) tailored for agriculture, utilizing severe weather warnings across various districts, states, and Union Territories.

Under the GKMS scheme, IMD actively monitors rainfall patterns and weather anomalies, issuing timely alerts and warnings to farmers. These alerts, conveyed via SMS, provide guidance on responding to extreme weather events and include actionable

measures. Such information is also shared with State Departments of Agriculture to facilitate effective disaster management. Agrometeorological Advisories are disseminated through various channels such as print and electronic media, Door Darshan, radio, internet, and SMS via the Kisan Portal. Additionally, private companies under Public Private Partnership (PPP) mode aid in distribution. The number of farmers receiving SMS alerts varies based on the farming population and cultivated area.

Farmers can access weather information, alerts, and tailored agrometeorological advisories specific to their districts through the 'Meghdoot' mobile app, launched by the Ministry of Earth Sciences. Another app, 'Kisan Suvidha', launched by the Ministry of Agriculture & Farmers Welfare, also provides access to these details, enhancing accessibility and usability for farmers. Social media platforms are utilized for rapid dissemination of weather forecasts and advisories to farmers. Currently, 16,140 WhatsApp groups cover farmers in 1,19,554 villages across 3,598 Blocks. These groups include officials from State Agriculture Departments at both district and block levels. Efforts are ongoing to expand coverage further, ensuring widespread distribution of Agrometeorological advisories via WhatsApp.

Furthermore, Agrometeorological advisories are disseminated through dedicated Facebook pages managed by AMFUs and DAMUs. Collaborative efforts with state governments have facilitated the integration of weather forecasts and advisories into state government mobile apps and websites. This integration has been successfully implemented in Bihar, Chhattisgarh, Gujarat, Haryana, Madhya Pradesh, Nagaland, Rajasthan, Tamil Nadu, and Uttarakhand. Approximately 6 million farmers across these states are benefiting from access to weather forecasts and tailored

agrometeorological advisories. IMD continues to actively promote its services among the farming community by organizing Farmers' Awareness Programmes (FAPs) in collaboration with AMFUs and DAMUs across the country. Additionally, IMD and experts from AMFUs and DAMUs participate in agricultural exhibitions like Kisan Melas and Farmers' Days to raise awareness about these services, ensuring more farmers can benefit from them. Under the umbrella Central Sector Scheme ACROSS, IMD is implementing various initiatives to advance forecasting capabilities and enhance Weather & Climate services nationwide, including Agromet Advisory Services. This scheme encompasses four sub-schemes: Atmospheric Observation Network (AON), Upgradation of Forecast System (UFS), Weather & Climate Services (WCS), and Commissioning of Polarimetric Doppler Weather Radars (PDWR). These efforts aim to expand the observational network and improve Weather & Climate services across India (Ministry of Earth Sciences, pib.gov.in).

CONCLUSION

Farmers strive to achieve optimal yields and improve their livelihoods despite relying heavily on rainfed agriculture. Access to weather forecast information is crucial for them. There is an urgent need for meteorological reports that are easily accessible and understandable to farmers. Integrating the delivery of weather information into agricultural policies and discussions is essential for enhancing farm risk management. Given the complexities of agricultural systems and the uncertainties associated with climate forecasts, a coordinated effort is necessary to ensure the routine use of this technology in agriculture moving forward. Agrometeorological stations should provide weather information at least one to two months before the onset of the rainy season. This



advance notice allows farmers to make critical decisions such as adjusting sowing schedules, selecting crop varieties, determining cropping ratios, intensifying production efforts, and allocating labour and capital effectively. Furthermore, weather forecasts provided by agro-meteorologists can support initiatives such as smart fertilizer subsidy programs and enhanced seed programs, promoting more efficient agricultural practices resulting in enhanced productivity and food security.

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We extend our sincere gratitude to the Indian Meteorological Department (IMD) for their unwavering dedication and continuous efforts to enhance the efficiency of weather forecasting. Their commitment to advancing

meteorological science and providing accurate forecasts has been invaluable in supporting various sectors, including agriculture, aviation, and disaster management.

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