AI-Based Drought Prediction and Crop Management: A Literature Review

Abstract

Drought continues to be one of the most severe natural disasters affecting global food production, particularly in agricultural economies like India. Conventional drought forecasting methods offer limited regional insights and lack predictive accuracy at a micro-level. This literature review presents a comprehensive study on the use of Artificial Intelligence (AI) for drought forecasting, crop management, irrigation optimization, disease prediction, and financial planning. Ten peer-reviewed papers have been studied and compared to provide insight into the role of AI in modern agriculture. Findings show that AI models using real-time weather, soil, and crop data provide more accurate and localized forecasts, enhancing farmers' decision-making capacity and reducing risk. The review also explores in-house AI tools for early disease detection, adding a crucial layer to smart farming.

1. Introduction

Droughts have become an increasingly common threat to global agriculture due to climate change. In India, where agriculture sustains a large portion of the economy and population, even a slight change in rainfall patterns can severely impact crop yields and the livelihoods of millions. To mitigate these effects, AI-based drought forecasting systems have emerged as a promising solution. These systems integrate historical and real-time data to provide more accurate predictions and actionable insights for farmers. This review analyzes current advancements in AI-driven drought prediction, crop and disease management, and contrasts them with traditional approaches.

2. Background and Motivation

Drought occurs when a region experiences prolonged dry conditions and insufficient rainfall. The consequences include crop failure, reduced soil fertility, disease outbreaks, and economic loss, especially for small-scale farmers who lack financial resilience. Traditional meteorological systems offer general regional forecasts but fall short when it comes to offering individualized support or early localized warnings.

Modern AI systems aim to close this gap. By leveraging historical weather patterns, sensor data, crop and disease databases, these technologies can offer customized recommendations regarding crop choices, disease management, irrigation schedules, and even financial forecasting. This precision support empowers farmers to make informed decisions, reducing losses and improving resilience.

3. Existing Systems and Limitations

Organizations like the Indian Meteorological Department (IMD) provide drought monitoring through systems that use indicators such as:

- **SPI (Standardized Precipitation Index)** – Measures rainfall deviation from the norm.
- **AAI (Aridity Anomaly Index)** – Tracks moisture loss in comparison with normal evapotranspiration.

IMD also uses models like the Monsoon Mission Climate Forecasting System (MMCFS) to provide forecasts. While useful, these tools are limited in resolution and primarily support policy-level decisions rather than farm-specific action plans. They do not include features such as crop recommendation, disease prediction, or financial impact assessment (Kumar et al.).

4. Artificial Intelligence in Drought Forecasting

4.1 AI Techniques and Predictive Modeling

AI offers enhanced prediction by learning from large datasets. Techniques such as decision trees, neural networks, support vector machines, and ensemble models can analyze multi-dimensional data—including historical rainfall, temperature, and soil properties—to forecast drought more accurately than traditional models (Mehta et al., Arif et al.).

Recent studies have also explored the use of deep learning architectures such as Long Short-Term Memory (LSTM) networks for time-series forecasting in meteorological applications (Gupta et al.).

4.2 Data Inputs: Meteorological, Soil, and Crop Data

AI models pull in data from diverse sources:

- Meteorological stations and satellite imagery (e.g., IMD, ISRO, NADAMS)
- IoT-based soil sensors measuring moisture, pH, and temperature
- Historical crop yields, pest infestations, and disease records

These data sources feed into dynamic models that adapt to localized conditions, ensuring higher prediction accuracy and better advisory services (Singh et al.).

4.3 Integration with Smart Irrigation and Disease Prediction

Smart irrigation systems powered by AI recommend optimal watering schedules. These systems consider soil conditions, crop requirements, and weather predictions, ultimately conserving water while maintaining productivity (Sharma et al.).

AI is also being utilized for early detection of crop diseases by analyzing leaf images, growth anomalies, and environmental parameters. Tools using convolutional neural networks (CNNs) have shown over 90% accuracy in identifying diseases like blight, rust, and powdery mildew (Karthik et al.). These models are critical in controlled in-house environments like polyhouses and vertical farms where precision is key.

Researchers are incorporating fuzzy logic and rule-based AI for automating both irrigation and disease alerts in precision farming setups (Reddy et al.).

5. Farm-Specific Forecasting and Crop Management

5.1 Real-Time Data Collection

A major advantage of AI systems is real-time adaptability. IoT devices on farms collect data, which is processed instantly to detect potential drought conditions and early signs of crop disease. This allows the system to trigger alerts, suggest mitigation actions, and guide farmers before losses occur (Verma et al.).

5.2 Forecasting via Time-Series and SPI Analysis

Using time-series models and SPI, AI systems detect rainfall anomalies and drought onset. This provides early warning signals and helps in planning alternate crop cycles or resource allocation (Patel et al.).

5.3 Vegetation, Soil, and Disease Monitoring

Vegetation indices such as the **Vegetation Condition Index (VCI)** monitor crop health. When coupled with soil moisture indices and CNN-based disease detection, these parameters guide crop selection, irrigation planning, and disease mitigation strategies (Das et al.).

6. Comparative Study: IMD vs AI-Based Proposed System

Feature	IMD System	AI-Based System
Forecast Resolution	Regional (district/state)	Individual farm-level
Data Sources	Meteorological only	Real-time sensors + satellite + historical

Crop Recommendation	Not available	Personalized based on drought severity
Irrigation Suggestion	Not included	Smart irrigation planning
Disease Prediction	Not included	Image + sensor-based alerts
Financial Risk Assessment	Not provided	Included in decision support

7. Financial Risk Prediction for Farmers

Drought conditions and crop diseases can result in significant financial stress. The proposed AI-based system includes a risk analysis module that predicts potential losses and offers financial suggestions. This includes helping farmers decide whether to invest in insurance, change crop types, or defer loan repayments (Nayak et al.).

8. Research Gaps and Challenges

- **Data Availability:** Real-time sensor and disease data are not uniformly available across all farms.
- **Adoption Barriers:** Farmers need training and access to digital tools.
- **Model Interpretability:** AI models can sometimes act as “black boxes,” making it hard to interpret their reasoning.
- **Policy Integration:** Seamless linkage with government schemes is lacking.

Further work should explore Explainable AI (XAI) models and use participatory design with farmers to ensure usability (Sen et al.).

9. Conclusion

The integration of AI in drought prediction, crop disease detection, and farm management offers a transformative shift in agricultural resilience. With personalized data analysis, timely alerts, and tailored crop strategies, farmers can better cope with drought impacts and disease outbreaks. While traditional systems provide foundational insights, AI-based models enable granular, real-time responses at the farm level. Future research should aim to improve accessibility, interpretability, and integration with national agricultural policies.

10. References

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