THE USE OF ARTIFICIAL INTELLIGENCE IN STUDYING TEMPERATURE RANGES IN TREE PLANTS: A COMPREHENSIVE REVIEW OF METHODOLOGIES, APPLICATIONS, AND CHALLENGES

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Abstract
This report provides a comprehensive review of the rapidly evolving field at the intersection of Artificial Intelligence (AI) and plant science, with a specific focus on the study of temperature ranges in tree plants. It synthesizes key methodologies, outlines transformative applications in precision forestry and urban planning, and conducts a critical analysis of the significant challenges that persist. The integration of AI, including deep learning, machine learning, and computer vision, with diverse data sources such as thermal imagery, LiDAR, and satellite remote sensing, has enabled high-precision monitoring of plant health, phenological changes, and the mitigation of abiotic stressors like heat and drought. However, the field is constrained by critical challenges, including data scarcity, model generalization issues across different species and ecosystems, and the inherent "black box" problem of many advanced AI models. This review concludes that while AI offers unprecedented potential to enhance our understanding of forest dynamics and build more resilient ecosystems, its full realization depends on addressing these foundational hurdles, particularly through advancements in Explainable AI (XAI) and multi-source data fusion.
Keywords: *AI, Temp*

Scope and Objectives of the Review:
This review provides a comprehensive overview of AI's transformative role, focusing on key methodologies, data sources, and applications for understanding temperature's impact on tree plants. It critically examines the field's limitations and explores emerging research frontiers that promise to overcome current barriers. By synthesizing current research, this report aims to provide a structured framework for understanding the technical landscape, identifying key challenges, and illuminating future directions for AI-driven plant research.

Methodology and Literature Review:
The Interplay of Climate and Tree Health: Temperature is a fundamental determinant of tree physiology, affecting metabolic rates, photosynthesis, and transpiration. As a direct and indirect driver of plant stress, temperature fluctuations pose significant challenges to sustainable forest management and agriculture. For example, high temperatures can induce cellular damage and lower photosynthetic activity, while low temperatures may suppress essential metabolic reactions. The increasing frequency of extreme events, such as heat waves and prolonged droughts, necessitates advanced tools to monitor and predict tree responses at scale. A comprehensive understanding of these temperature-driven responses is crucial for predicting the fate of global forests in a future warmer world.

The Emergence of AI as a Transformative Tool in Forestry and Plant Science: Traditional methods for studying the effects of temperature, such as destructive sampling for stem water potential (Ψs) or labor-intensive sensor deployment, are often complex, non-continuous, and limited in scale. These methods struggle to provide the real-time, large-scale data required for effective management in a rapidly changing climate. The integration of AI offers a paradigm shift by enabling the extraction of hidden patterns from massive, heterogeneous datasets and providing real-time analysis and prediction in complex scenarios. AI's demonstrated success in diverse sectors, from precision medicine to smart agriculture, validates its potential to address the multidimensional complexities of forestry. This integration is moving the field from reactive responses to proactive prevention strategies by enabling early detection and timely intervention.

Result and Discussion:
The selection of an appropriate AI model is critical for addressing specific research questions. The field has seen successful applications of several model types, chosen for their specific strengths in handling different data structures and problem types. Tree-based ensemble methods like Random Forest (RF) and Gradient Boosting (XGBoost) are highly effective for regression tasks. RF, which aggregates the output of multiple decision trees, is

used for streamflow classification based on geospatial and climate data, including temperature.

Leaf and Canopy Temperature Prediction:
Temperature is a direct indicator of plant physiological processes, making its measurement and prediction central to agricultural and forestry management. AI models are being used to predict leaf temperature from environmental data, reducing reliance on costly and labor-intensive sensors. A model using Gradient Boosting achieved a high

Predicting Water Stress and Stomatal Regulation:
Water stress is intrinsically linked to temperature, as heat can increase transpiration and accelerate water loss. AI models can predict water status parameters like stem water potential (Ψs) from infrared thermal imagery and weather data. Studies on cherry trees have shown that supervised machine learning models like XGBoost and Random Forest can achieve significant correlation coefficients (R=0.83 and R=0.81) for this purpose, with weather variables having a higher weight in the models than vegetation indices. This capability offers a scalable solution for real-time irrigation management, assisting in optimizing water use efficiency.

Modeling Temperature's Effect on Tree Phenology:
Phenology, the study of seasonal life-cycle events such as leaf unfolding and flowering, is a sensitive indicator of climate change. AI models are proving to be more accurate than traditional Eco physiological models in predicting events like leaf unfolding date (LUD). A study using Gradient Boosting Decision Tree (GBDT) models found them to be more effective and better at capturing the response of LUD to climate warming, suggesting that traditional models may underestimate this response.

Conclusion:
The integration of AI into the study of temperature ranges in tree plants represents a fundamental shift in our ability to monitor, predict, and manage forest ecosystems in an era of rapid climate change. From high-precision modeling of water stress and phenological events to the design of resilient urban landscapes, AI offers unprecedented tools for enhancing both ecological understanding and practical management.

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