



The Role of AI in the Smart Monitoring of Trees: Leveraging Advanced Technologies for Sustainable Forest Management


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ABSTRACT

The development and integration of Artificial Intelligence (AI) combined with the Internet of Things (IoT) and the Internet of Trees (IoTr) have taken forest monitoring and management to a next level of advancement. Some key applications of AI are climate data analysis, disease and pest detection, and wildfire prediction and management. The IoTr offers different types of data collection using sensors that include soil moisture, temperature, humidity, and certain volume rates of tree sap flow. The use of AI and IoTr in forest monitoring offers several benefits; however, several issues and challenges remain to be addressed like data quality, model reliability, and compatibility with existing systems. Future work should address these challenges by enhancing the accuracy of AI models, ensuring data privacy and security, and developing ethical considerations.

1. INTRODUCTION

Smart Forestry means a deep integration of next-generation information technologies, including the Internet of Things (IoT), big data, cloud computing, artificial intelligence (AI), mobile Internet, and 3S technology (GIS, RS, GPS). These advanced technologies help in many ways with forestry, from production, cultivation, and management to protecting forests. Covering an area of about 33% of the

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world's land mass, forests produce clear air, pure water, and a home for thousands of animals (Ollinger, 2003). The primary elements of forests are trees, and they are fundamental to keeping ecological balance and protecting biodiversity (Commission, 2010; Council, 2023; Trust, 2023). Trees are important in producing oxygen, as estimates show that one-fifth of the world's oxygen comes from Amazon forests alone. However, in today's world, where people are demanding more and more resources for increased consumption and population, this kind of exploitation exerts tremendous pressure on these natural systems. That exploitation has caused half the world's rainforests to disappear within a century, with complete extinction likely in our lifetimes. Furthermore, nearly 80 million acres of land in the National Forest System of the United States are at risk from insects, diseases, or fire, and one-third of this land faces a very high-level threat (Pardikar, 2022; Sampson, 2008)

Continuing effective forest management in changeable environmental circumstances necessitates new tools for revealing flexible knowledge and forecasting forest dynamics. The application of AI in forest management functions mainly as an aid to prediction and a greater understanding of forest processes. AI's ability to analyze large-scale data sets complements how predictions about tree growth, health, and resilience can be upgraded. It is critical to apply specific types of AI to monitor individual trees and their health. Trees are the most essential components of forests (Harry & Thorpe, 1994). Current agricultural and land use practices are significant sources of greenhouse gas emissions that contribute nearly 25 percent to the world's total. Agriculture is a major driver of deforestation, which ranks among the top three human sources along with transportation and energy production (Hudson, 2013).

In Smart Forestry, problems of types with volumes of data that are beyond human capacity to handle, such as large-scale tree growth of composition becoming more and more important, machine learning (ML) and data analysis can help dig into records to better understand what has been going on all along. In addition to predicting tree growth and health when growth begins, these technologies can also locate sick forests or those affected by pests, depending on the environmental background. They can also help optimize forest management strategies. Furthermore, in analyzing surveillance data generally, it is thought that living things (including humans), ecosystem satellites, and drones provide useful information about conditions in the forest. They also assist with such things as aid for conservation and monitoring efforts (Wani & Sahoo, 2020)

In 2015, the U.S. Forest Service initiated the Smart Forests project as a platform to spread forest resources monitoring networks and ecosystems throughout the United States far and wide. Part of this task requires sensors with various capabilities at observation posts to monitor parameters of forest environmental quality, linked by wireless transmission networks to provide real-time feedback (Pappas et al., 2021). Explicitly, these sensors are focused on an evaluation of tree health parameters so that scientists can use AI to analyze real-time data on such tree health aspects as sap flow, canopy temperature variations, and chlorophyll level in leaves - three indicators that indicate the physiological state of an individual tree.

The main goal of this chapter is to investigate the revolutionary role AI and intelligent agents play in the smart management of forests. By using state-of-the-art technologies such as unmanned aerial vehicles (UAV) imaging, geographic information system (GIS) spatial database systems, and responder state (RS) response models, this chapter illustrates how data collection, analysis, and feedback mechanisms have been upgraded. In doing so, there is a basis for addressing the many challenges facing forest ecosystems. This chapter hopes to give readers a thorough explanation of how AI and IoT will benefit forestry, and through which ways it may protect the health and sustainability of future generations after us. Displaying the integration of AI, IoT, and IoT, this chapter is meant to present modern modes of forestry and conservation.

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