

Integrating GIS, IOT and AI for Climate-Resilient Urban Forestry: a Smart Framework for Tree Planting Strategies

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Accepted 29 May 2026

Approved 28 June 2026

Abstract— Tree planting plays a critical role in enhancing climate resilience through carbon sequestration, urban heat reduction, biodiversity enhancement, and air quality improvement. However, conventional urban forestry approaches often face limitations in spatial accuracy, monitoring efficiency, and long-term scalability. This study proposes an integrated smart urban forestry framework that combines Geographic Information Systems (GIS), Internet of Things (IoT) sensor networks, remote sensing technologies (Sentinel-1 and Sentinel-2), and Artificial Intelligence (AI)-driven predictive analytics to support data-driven tree planting and environmental management. The proposed framework integrates multi-source geospatial datasets, real-time environmental monitoring, and a Random Forest machine learning model to enhance site suitability analysis, species selection, growth prediction, and adaptive maintenance planning. Pilot implementations conducted in Sukabumi and Bogor, Indonesia, demonstrate measurable environmental and operational improvements, including approximately 20% improvement in tree survival rates, a reduction in urban heat island intensity of up to 2°C, and nearly 10% reduction in maintenance costs. The findings indicate that integrating GIS, IoT, remote sensing, and AI can significantly enhance climate-resilient urban forestry, sustainable ecosystem management, and evidence-based urban planning.

Index Terms— Urban Forestry, Climate Resilience, GIS, IOT, AI, Remote Sensing, Smart Cities.

I. INTRODUCTION

As urbanization continues to accelerate, cities increasingly face environmental challenges such as declining air quality, intensified urban heat islands, biodiversity loss, and rising vulnerability to climate-related events [1]. Urban forestry has emerged as an effective strategy for improving climate resilience through carbon sequestration, pollutant absorption,

temperature regulation, and ecosystem restoration [2]. However, conventional tree planting approaches often lack spatial precision, real-time monitoring capabilities, and predictive decision-making mechanisms necessary for sustainable long-term urban forestry management.

Recent advancements in Geographic Information Systems (GIS), Internet of Things (IoT) technologies, remote sensing, and Artificial Intelligence (AI) provide new opportunities for developing intelligent and data-driven urban forestry systems. GIS enables spatial suitability analysis and optimal site selection based on environmental and urban conditions [3], while IoT sensors support continuous monitoring of soil moisture, air quality, temperature, and tree health conditions [4]. In addition, remote sensing platforms and AI-driven predictive analytics improve environmental assessment, species suitability analysis, and long-term ecosystem management through advanced spatial and temporal analysis [5]. This study investigates how the integration of GIS, IoT, remote sensing, and AI can support climate-resilient urban forestry and enhance sustainable environmental planning.

The main contributions of this study are as follows:

- 1) Development of an integrated GIS-IoT-AI framework for climate-resilient urban forestry;
- 2) Integration of remote sensing and IoT-based environmental monitoring for real-time analysis;
- 3) Application of the Random Forest machine learning algorithm for predictive tree growth and species suitability analysis;
- 4) Validation of the proposed framework through pilot implementations in Sukabumi and Bogor, Indonesia.

The remainder of this paper is organized as follows. Section II reviews related studies on GIS, IoT, remote sensing, and AI applications in urban forestry. Section III presents the proposed methodology, data integration framework, and machine learning implementation. Section IV discusses the experimental findings, environmental impacts, and pilot implementation results. Finally, Section V concludes the study and outlines future research directions for AI-driven climate-resilient urban forestry systems.

II. LITERATURE REVIEW

1. Climate Resilience and Urban Forestry

Urban forestry serves as a vital strategy for mitigating climate change impacts by improving air quality, reducing urban heat islands, enhancing biodiversity, and supporting ecological sustainability [6]. Achieving these environmental benefits, however, requires accurate site selection, appropriate tree species allocation, and sustainable long-term maintenance strategies. Advanced Geographic Information Systems (GIS), combined with remote sensing and environmental analytics, provide data-driven approaches for identifying optimal planting locations and improving climate-resilient urban forestry planning.

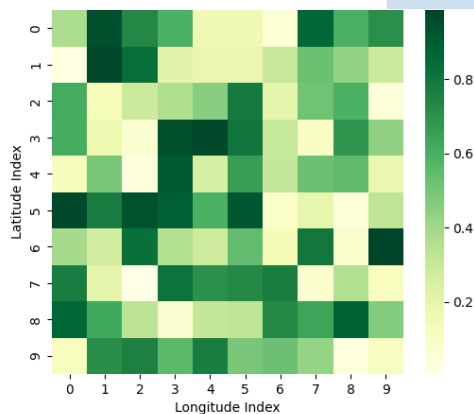


Figure 1. GIS-Based Spatial Suitability Analysis for Climate-Resilient Tree Planting.

Figure 1 illustrates a GIS-based spatial suitability model used to evaluate environmental conditions for climate-resilient tree planting. The spatial analysis integrates geospatial indicators such as land use, vegetation coverage, soil characteristics, and urban heat distribution to identify optimal planting zones. This approach supports evidence-based urban forestry planning and enhances long-term ecological sustainability.

2. Geographic Information Systems (GIS) in Urban Forestry

GIS has revolutionized urban forestry through precise spatial analysis, mapping, and monitoring. Studies underscore GIS's effectiveness in identifying optimal planting sites based on soil composition, climate

conditions, and land use [7]. Advanced GIS applications, such as multi-criteria decision analysis (MCDA) and predictive spatial modeling, enhance site suitability assessments, yet challenges persist regarding data integration and accessibility. [8]

3. Internet of Things (IoT) for Environmental Monitoring

IoT technologies facilitate real-time environmental monitoring and support proactive decision-making in urban forestry systems. IoT sensors continuously collect environmental data such as soil moisture, temperature, humidity, and air quality, enabling more effective monitoring of tree health and environmental conditions [9]. Previous studies indicate that IoT-driven precision forestry can improve tree survival rates, optimize maintenance operations, and enhance environmental sustainability (Patel & Singh, 2023). However, challenges related to sensor reliability, real-time data transmission, and integration with GIS platforms remain important considerations in smart urban forestry implementation.

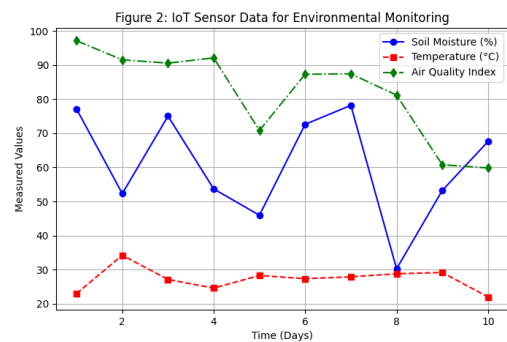


Figure 2. IoT-Based Environmental Monitoring and Real-Time Sensor Data Analysis.

Figure 2 illustrates the integration of IoT sensors for real-time environmental monitoring within climate-resilient urban forestry systems. The figure demonstrates how environmental telemetry, including soil moisture, temperature, and air quality measurements, can be continuously monitored and analyzed to support adaptive tree maintenance, environmental assessment, and data-driven urban forestry management.

4. Remote Sensing and Satellite Data for Vegetation

Remote sensing technologies, including optical and radar satellite imagery, provide critical insights into vegetation health, land cover dynamics, and environmental stress conditions. Sentinel-1 and Sentinel-2 satellites enable continuous environmental monitoring, while Synthetic Aperture Radar (SAR) supports vegetation analysis under varying weather and atmospheric conditions (Kim & Park, 2020). The integration of remote sensing data with GIS and AI-based analytics enhances environmental assessment capabilities and improves long-term urban forestry planning.

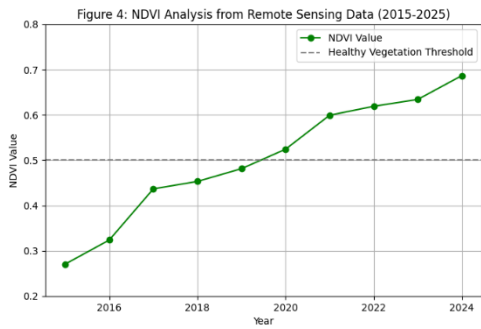


Figure 3. NDVI-Based Vegetation Health Analysis Using Remote Sensing Data (2015–2025).

Figure 3 presents the temporal analysis of vegetation health using the Normalized Difference Vegetation Index (NDVI) derived from remote sensing data between 2015 and 2025. The upward trend in NDVI values indicates improvements in vegetation density and ecological conditions over time, demonstrating the potential contribution of urban greening and climate-resilient tree planting strategies. These remote sensing insights support environmental monitoring, predictive analytics, and evidence-based urban forestry decision-making.

5. Artificial Intelligence (AI) in Data Analytics

AI-driven approaches, particularly machine learning and deep learning techniques, are increasingly transforming environmental research through data-driven decision-making and predictive analytics in urban forestry. The integration of AI with GIS, IoT, and remote sensing technologies enables advanced environmental analysis, species suitability assessment, and predictive tree growth modeling for climate-resilient urban ecosystems [10]. These intelligent systems support sustainable urban forestry management by improving planning accuracy, environmental monitoring, and adaptive maintenance strategies.

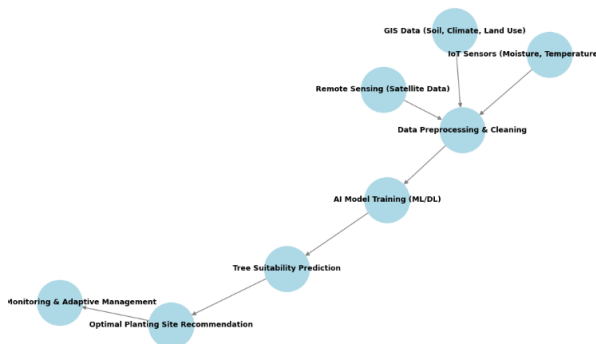


Figure 4. AI-Based Predictive Framework for Climate-Resilient Tree Planting Optimization.

Figure 4 illustrates the integration of GIS data, IoT sensor monitoring, remote sensing imagery, and AI-based predictive analytics within an intelligent urban forestry framework. The proposed model supports tree

species suitability analysis, growth prediction, and environmental stress detection using machine learning techniques. This integrated approach enhances predictive accuracy and contributes to long-term sustainability and climate resilience in urban forestry management.

III. METHOD

The methodology for optimizing tree planting for climate resilience integrates advanced geospatial technologies, Internet of Things (IoT) devices, and sophisticated data analytics. This chapter details the systematic approach and technological tools employed to achieve precise spatial analysis, real-time monitoring, and data-driven decision-making for urban forestry initiatives. The combination of Geographic Information Systems (GIS), IoT, remote sensing data, and artificial intelligence (AI) algorithms forms the backbone of this methodology, enabling the optimization of tree planting strategies to enhance urban climate resilience.

1. Geospatial Data Collection and Analysis in Tree Planting for Climate Resilience

The collection and analysis of geospatial data play a critical role in supporting climate-resilient urban forestry and coordinated tree planting strategies. By integrating spatial information from multiple environmental sources, urban planners can identify optimal planting locations and maximize ecological benefits. High-resolution satellite imagery from Sentinel-1, Sentinel-2, Landsat, and commercial remote sensing platforms enables the assessment of vegetation health, land cover distribution, and urban infrastructure conditions. In addition, aerial imagery and LiDAR-based mapping provide detailed spatial information regarding terrain elevation, vegetation canopy structure, and environmental characteristics relevant to urban forestry planning.

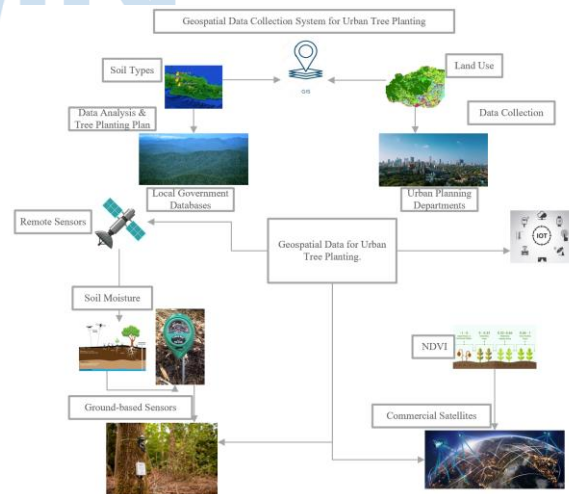


Figure 5. Geospatial Data Collection and Multi-Source Environmental Integration System.

Figure 5 illustrates the integrated geospatial data collection framework used for climate-resilient urban forestry analysis. The system combines GIS datasets, remote sensing imagery, IoT sensor monitoring, and environmental field observations within a centralized analytical architecture. This multi-source integration supports spatial analysis, environmental assessment, and evidence-based decision-making for intelligent urban tree planting and long-term ecosystem management.

2. Data Integration & Spatial Analysis

Data integration and spatial analysis stand at the core of any GIS-based decision-making process. The ability to integrate diverse datasets including satellite imagery, climate data, and terrestrial data deepens the accuracy of spatial analyses. Unfortunately, data integration continues to be a multidimensional challenge that requires strong data management systems and frameworks for interoperability. Multi-source data fusion thus plays a critical role, where satellite imagery, aerial photography, LiDAR mapping, and field survey data can be combined in a seamless way to develop a comprehensive urban analysis. The ability to layer different spatial layers and indicators, including soil types, land uses, vegetation cover, and infrastructure networks enable a deep site assessment and zoning management capabilities for environmental monitoring. Successful preprocessing and georeferencing to standardize, clean, and align datasets are essential for effective spatial assessments to ensure spatial information is both accurate and consistency.

In addition to data integration, advanced site selection and suitability analysis are informed by the development of clear criteria based on weighted evaluations of various factors of interest and assessment such as soil quality, water availability, and urban heat island severity to identify optimal tree planting sites. These criteria for analysis can then be refined via GIS-based spatial overlays and rankings of sites that should be prioritized across the management plan to achieve the most beneficial placement. To distinguish extremes of urban heat relevance and possible vegetation indices to identify potential areas for environmental or urban heat control, additional approaches include employing heat maps to identify relative distances associated with spatial attributes detected across the urban landscape [11].

3. Mapping, Visualization, and Real-Time Insights for Climate-Resilient Urban Forestry

GIS, IoT, and AI technologies support real-time environmental monitoring, spatial visualization, and predictive analytics for climate-resilient urban forestry. GIS platforms integrate satellite imagery, LiDAR, and aerial data to identify optimal planting locations and evaluate vegetation conditions, while IoT sensors continuously monitor environmental parameters such as soil moisture, temperature, humidity, and air quality. The integration of machine learning with historical and real-time environmental data further enables predictive analysis of tree growth, survival probability, and

ecosystem conditions to support adaptive urban forestry management [12].

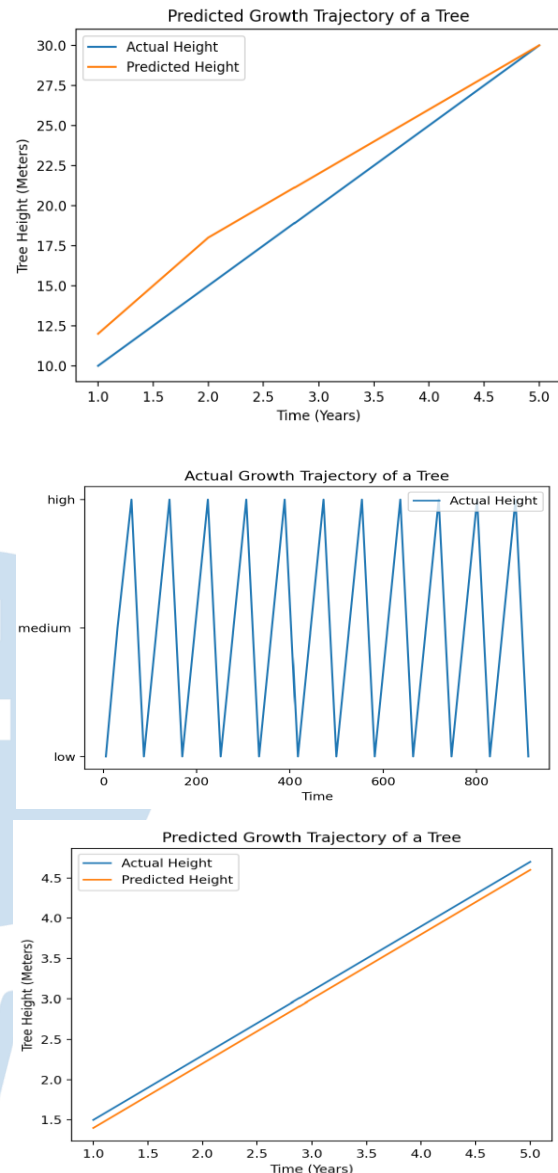


Figure 6. AI-Based Tree Growth and Survival Prediction Model.

Figure 6 illustrates the predictive analytics framework used to estimate tree growth trajectories and survival probabilities using GIS, IoT sensor data, and machine learning techniques. The model integrates environmental variables such as soil moisture, temperature, and vegetation conditions to support intelligent tree species selection and long-term climate-resilient urban forestry planning.

Table 1 presents sample environmental monitoring variables used for predictive tree growth analysis. The relationship between tree density, soil moisture, environmental conditions, and tree height demonstrates the importance of IoT-based monitoring systems in supporting adaptive and data-driven urban forestry management.

Table 1: Environmental Monitoring Variables for Tree Growth Prediction.

Name	Trees	Tree Height	Environmental Factor	Soil Moisture	Time
Aceh	487	low	8.000000	0.700000	5.000000
Bali	2987	medium	15.000000	0.900000	30.000000
Bangka Belitung	5487	high	11.000000	1.000000	60.000000
Banten	7987	low	14.333333	1.166667	86.666667
Bengkulu	10487	medium	15.833333	1.316667	114.166667

4. Mapping & Analysis

Mapping and spatial analysis are invaluable in understanding environmental trends, getting a sense of land-use change, and evaluating how green infrastructure projects such as urban forestry are achieving their goals. Advanced analytics provide stakeholders with more precise information about the amount of vegetation cover, the species of plants and animals within a given area, and the increased ecological benefits of tree-planting efforts in urban communities. Within GIS mapping platforms, amendment of sensor-generated data visualizes real-time environmental state or conditions, allowing information to inform decision-making in relevant time elements. Temporal analysis of conditioned shapes the process, as tracking environmental change or the condition of a tree is a gradient of time, allowing for adaptation of management and improved predictions about the sites for effort.

Implementation strategies ideally become supportive of this process via the use of GIS and remote sensing technology, which is used to identify priority sites for sensor deployment and maximize spatial extent and coverage. Centralized management systems and data platforms allow for the automatic processing of data, which helps organize large sets of environmental information to be more effective in decision-making. Responsible use of measurement factors, including regular maintenance and calibration of sensors, will ensure the reliability and accuracy of the measurement process. Effective delivery of information occurs in platforms with interactive dashboards and stakeholder collaborative spaces for transparent communication and research dissemination with an evidence-based approach.

The linkage of mapping, spatial analytics (including sensing), and IoT data produce a number of benefits, including specific insights that allow for smart decision-making. Specific insights optimize tree species selection, planting schedules, and management

practices to improve outcomes since well-designed practice plans will rely less on conditioned observation and more on empirically supported decisions. Resource efficiency is improved through data-supported management of fertilization and activities that will increase sustainability.

5. Remote Sensing, Data Analytics, and AI for Climate-Resilient Tree Planting

Remote sensing, GIS, IoT, and artificial intelligence (AI) provide an integrated framework for climate-resilient urban forestry. Satellite imagery from Sentinel-1, Sentinel-2, and Landsat supports the analysis of vegetation health, land cover, soil moisture, and urban heat conditions, while preprocessing techniques such as spatial calibration and cloud removal improve data quality for environmental analysis [13]. Geospatial overlays and vegetation indices, including NDVI and EVI, further assist in identifying priority areas for urban greening and environmental restoration.



Figure 7. Environmental and Climatic Data Collection Framework.

Figure 7 illustrates the integration of remote sensing imagery, IoT sensor monitoring, GIS datasets, and AI-based analytics within a unified environmental data collection framework. Machine learning models process multi-source environmental data to predict tree growth, species adaptability, and survival probability, supporting adaptive and data-driven urban forestry management for long-term climate resilience.

5.1. Data Processing for AI-Driven Insights:

Data processing is essential for ensuring accurate and reliable AI-based spatial analysis in urban forestry. The preprocessing workflow includes data cleaning, normalization, feature engineering, and integration of geospatial, environmental, and IoT sensor datasets to improve machine learning performance and predictive accuracy. Techniques such as Min-Max normalization, Z-score normalization, and One-Hot Encoding are applied to standardize environmental variables and support effective AI-driven decision-making for climate resilience.

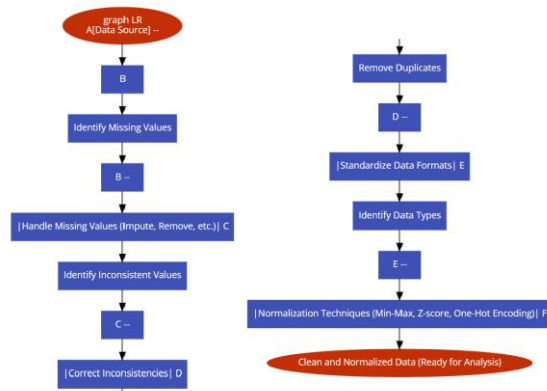


Figure 8. Data Cleaning, Normalization, and Integration Workflow for AI-Based Environmental Analysis.

Figure 8 illustrates the preprocessing pipeline used to prepare multi-source environmental datasets for machine learning applications. The workflow includes handling missing values, removing inconsistencies and duplicates, standardizing data formats, and applying normalization techniques before integrating the datasets into a unified analytical framework.

5.2. Data Analysis Techniques:

Data analytics methods, which include machine learning models, predictive analytics, and statistics, are applied to derive useful insights from spatial databases that assist with decision making in GIS and AI-based studies within the environment. Descriptive analytics relies on statistics to summarize, interpret, and visualize past and present environmental data in order to understand the existing condition and trends over time. These steps provide a foundation for future analytics that apply advanced machine learning algorithms, in predictive analytics, to making forecasts about future environmental conditions, tree growth, and tree survival probabilities based on historical data and patterns from the now. Recent studies have shown how AI-based predictive models can refine tree planting approaches by ensuring the right tree is planted in the right location at the right cost and with the right adaptability with urban forestry strategies [14].

5.3. Applications of AI in Tree Planting:

Artificial Intelligence (AI) enhances urban tree planting through data-driven site selection, species suitability analysis, and predictive environmental assessment. Machine learning models analyze geospatial and environmental variables such as soil conditions, climate, water availability, and urban heat distribution to identify optimal planting locations and support

sustainable urban forestry planning. AI-based decision support systems further improve climate resilience by enabling adaptive and efficient tree management strategies.

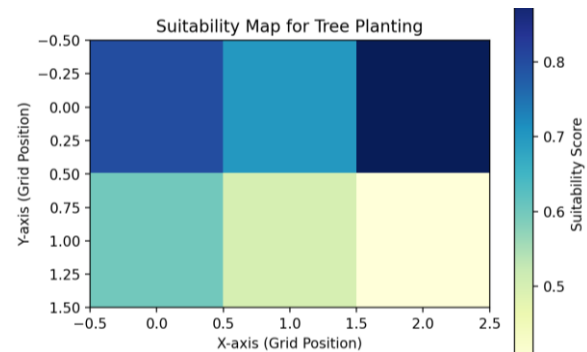


Figure 9. AI-Based Site Selection and Suitability Analysis for Urban Tree Planting.

Figure 9 illustrates the AI-driven suitability analysis framework used to identify optimal tree planting locations based on environmental, climatic, and geospatial factors for climate-resilient urban forestry management.

5.4. Smart Tree Species Selection:

Selecting suitable tree species for urban environments requires the analysis of climatic, environmental, and geospatial conditions. In this study, a Random Forest-based machine learning model is applied to support intelligent tree species selection using GIS, IoT, and remote sensing data, including soil moisture, temperature, NDVI, and historical tree growth records. The model is formulated as a supervised learning approach, where environmental variables are used as input features $X = \{\text{soil moisture, temperature, NDVI, rainfall, land surface conditions}\}$, while the output variable Y represents tree species suitability classes (suitable / moderately suitable / not suitable) and predicted survival probability.

The dataset is divided into training and testing sets using an 80:20 split. The Random Forest algorithm constructs multiple decision trees and aggregates their outputs to improve prediction stability and reduce overfitting. Model performance is evaluated using classification accuracy and feature importance analysis to identify the most influential environmental factors affecting tree suitability. The trained model enables data-driven prediction of species suitability, tree growth potential, and survival probability, supporting adaptive and climate-resilient urban forestry planning.

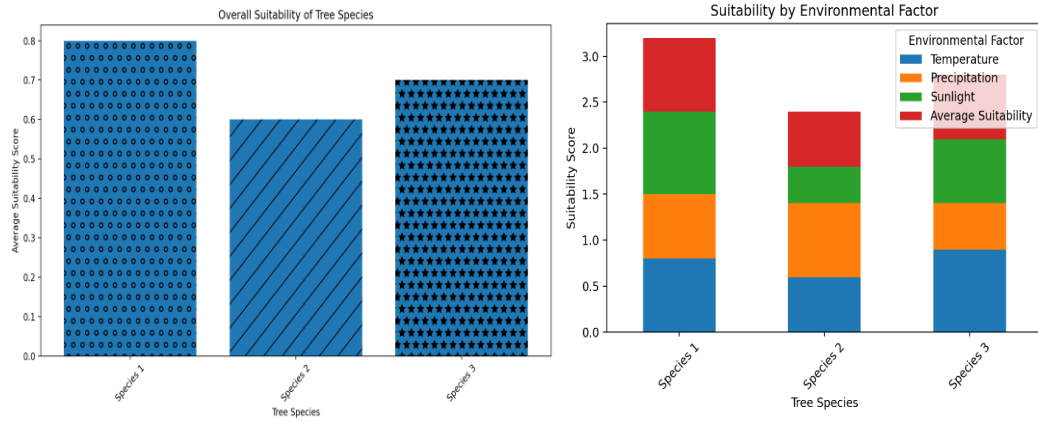


Figure 10. Random Forest-Based Tree Species Suitability Prediction Model.

Figure 10 illustrates the complete machine learning pipeline, including data preprocessing, feature selection, model training, and prediction stages. The framework integrates GIS spatial layers, IoT sensor data, and remote sensing indicators to generate predictive suitability maps for urban tree planting optimization.

5.5. Intelligent Tree Monitoring and Maintenance:

Monitoring and managing urban forests increasingly depend upon real-time data insights and predictive analysis to ensure sustainability and health of the ecosystem. “AI-assisted urban forest monitoring relies on IoT, remote sensing, and machine learning technologies to support real-time assessment of tree health and environmental conditions. AI-based predictive models analyze satellite imagery, drone data, and sensor information to detect stress, pest infestations, and abnormal growth patterns, enabling proactive and adaptive maintenance strategies. These approaches improve resource efficiency, reduce maintenance costs, and strengthen long-term urban ecosystem resilience.

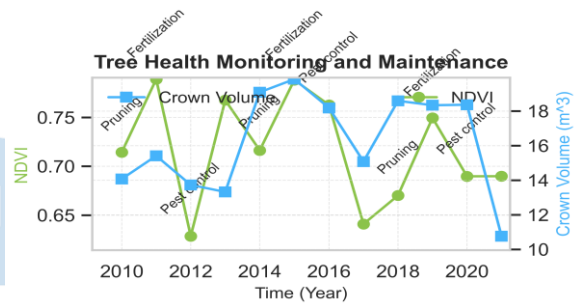
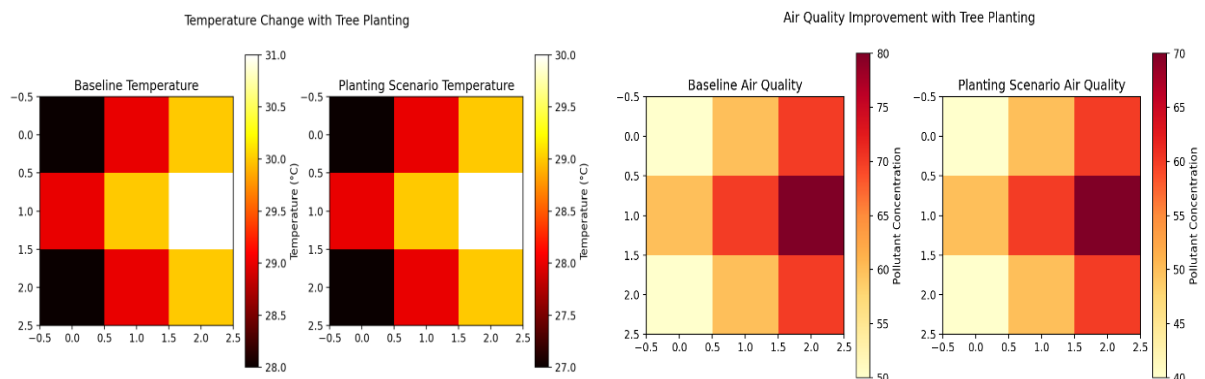


Figure 10. AI-Based Tree Monitoring and Predictive Maintenance Framework.

Figure 11 illustrates the integration of AI analytics, remote sensing, and IoT sensor monitoring for intelligent tree health assessment and predictive maintenance in climate-resilient urban forestry management.

5.6. Advanced Impact Assessment:

AI-assisted monitoring supports continuous assessment of urban forest health using indicators such as NDVI, crown volume, and environmental sensor data. By correlating maintenance activities including pruning, fertilization, and pest control with vegetation changes over time, the system enables early stress detection, adaptive management, and optimized maintenance scheduling for sustainable urban forestry.



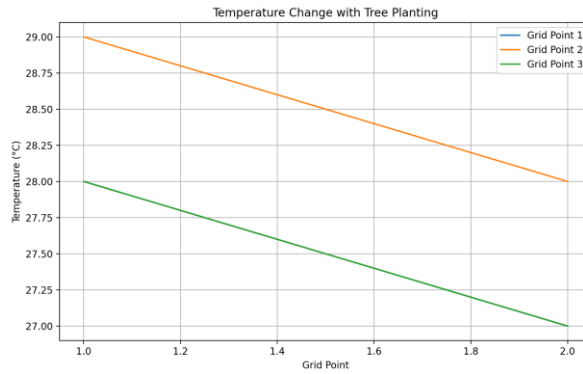


Figure 11. AI-Based Climate Resilience and Environmental Impact Modeling.

Figure 12 illustrates predictive climate resilience modeling using AI-driven spatial analysis and environmental monitoring data. The heat maps and temporal analysis demonstrate reductions in urban surface temperature and improvements in air quality associated with increased vegetation coverage and urban tree planting initiatives [15].

6. Plan to Implement AI in Urban Forestry

The integration of AI and GIS in urban forestry supports scalable, data-driven, and sustainable environmental management. AI frameworks such as TensorFlow and scikit-learn analyze data collected from IoT sensors, remote sensing platforms, and GIS databases to support predictive modeling and urban forestry planning. Cloud-based spatial databases and secure data management systems further improve data accessibility, monitoring, and decision-making efficiency.

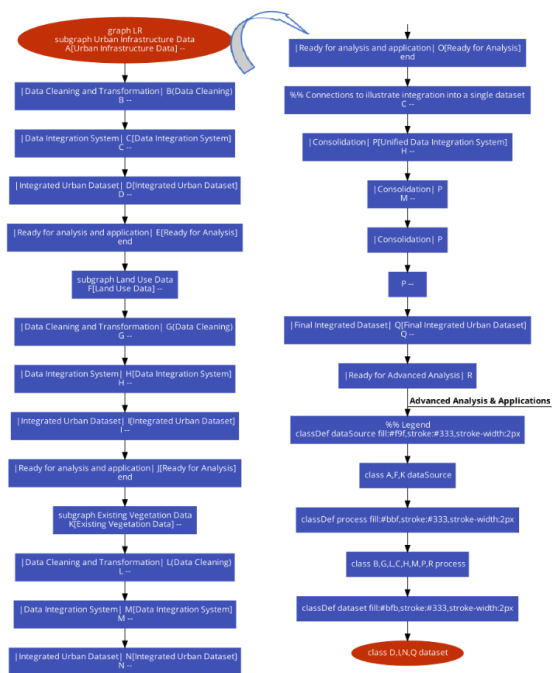


Figure 12. Urban Infrastructure and Environmental Data Integration Framework.

Figure 13 illustrates the integration of GIS, IoT sensors, remote sensing data, and AI analytics within a centralized urban forestry management system. The framework supports predictive analysis, environmental monitoring, and adaptive decision-making for climate-resilient urban ecosystem management.

7. Implementation of Artificial Intelligence and Staging in Urban Forestry

The effective application of Artificial Intelligence (AI) and analytics programs for urban forestry must be married to a comprehensive process that includes technology development, validation with pilot projects, and stakeholder interaction. Platforms such as ArcGIS, R, QGIS, and Apache Spark provide a base for analysis of spatial data in large areas; AI frameworks, such as TensorFlow, PyTorch, and scikit-learn, enable predictive modeling and decision support based on those spatial data. Some geospatial AI systems, such as Google Earth Engine, allow for capacity for analysis of high-resolution satellite image data for vegetative health and land cover. Piloting technologies in multiple contexts is an important aspect of the process, including the integration of IoT sensors and remote sensing for urban forestry contexts. Performance metrics, such as tree survival, soil moisture stability, and reductions in the urban heat island effect inform iterative modeling for improvements while the pilot project is also designed for scaling and reliability [16], [17].

To broaden the influence of AI-enhanced urban forestry, research into scalability and replication is necessary. Knowledge gained from pilot projects will help refine our models to varying contexts whether the environmental or socio-economic context. Cooperatives among governments, organizations, and communities will further allow for organizational and cooperative data sharing and more collaborative efforts. Real-world AI-driven monitoring utilizes real-time IoT data that works in tandem with AI integration into real-time dashboards while offering future forecasting capabilities on potential environmental threats like drought stress, pest outbreaks, or nutrient deficiencies [18]. Capacity building and participatory platforms engage stakeholders through training, citizen science, and education efforts on the public's capacity

for environmental collaboration [19]. Finally, as a cycle of continuous improvement practices, we will collect and analyze performance regularly using key indicators, such as climate resilience, air quality, and biodiversity, as a basis for takes for continuous improvement. The goal of these interconnected strategies contributes to the larger goal of establishing AI as an enabler of smarter, adaptive, and sustainable urban forestry systems [20], [21].

IV. RESULT AND DISCUSSIONS

1. Results

Pilot implementations in Sukabumi and Bogor demonstrated the effectiveness of the proposed framework for urban forestry management. In Sukabumi, the integration of GIS, IoT monitoring, remote sensing, and Random Forest-based predictive analysis improved tree survival rates by approximately 20% and reduced urban heat island intensity by about 1.5–2°C. In Bogor, AI-assisted predictive maintenance and environmental monitoring reduced tree mortality by 15% and maintenance costs by approximately 10%.

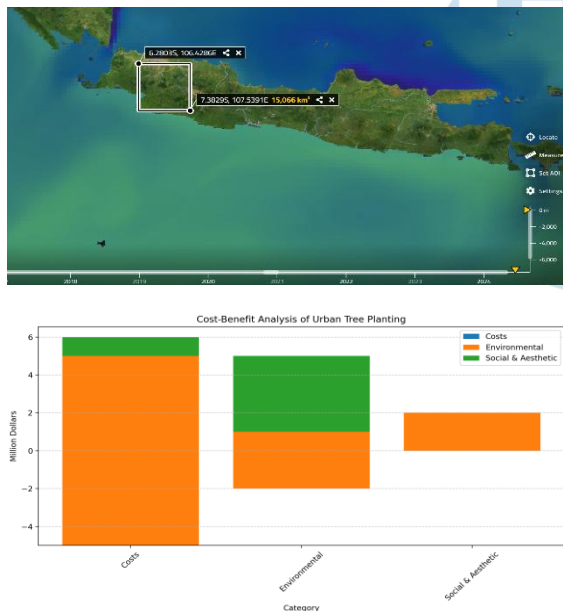


Figure 13. AI-Driven Urban Forestry Implementation and Cost-Benefit Analysis in Sukabumi and Bogor.

Figure 14 illustrates the regional implementation of the proposed GIS-IoT-AI framework in Sukabumi and Bogor together with the economic and environmental cost-benefit analysis. The results demonstrate improvements in tree survival, urban cooling, maintenance efficiency, and long-term sustainability through AI-assisted urban forestry management.

The environmental impact assessment further demonstrated improvements in air quality, urban cooling, and ecosystem sustainability. Economic analysis indicated that an estimated investment of \$7 million generated approximately \$20 million in environmental and social benefits, resulting in a

positive net present value (NPV) of nearly \$13 million. These findings confirm the effectiveness of integrating GIS, IoT, remote sensing, and AI technologies for sustainable and climate-resilient urban forestry management.

Table 2 presents the economic and environmental valuation of AI-driven urban forestry implementation, including project costs, maintenance expenses, carbon sequestration benefits, energy savings, and public health impacts [22].

Table 2: Economic Impact of AI-Driven Urban Tree Planting.

Category	Cost/Benefit	Units	Valuation Method
Project Costs	-\$5 million	Million	Direct Costs
Maintenance Costs	-\$2 million/Year	Annual Costs	
Total Costs	-\$7 million	Million	
Carbon Sequestration	\$10 Million	Tons CO ₂	Carbon Credit Price
Energy Savings	\$3 Million/Year	Annual Savings	Reduced Cooling Costs
Air Quality Improvement	\$2 Million	Million	Replacement Cost Approach
Property Value Increase	\$1 Million	Million	Hedonic Pricing Studies
Public Health Benefits	\$4 Million	Million	Willingness to Pay Approach
Aesthetics	\$3 Million	Million	
Total Benefits (present value)	\$20 Million	Million	Discounted Future Benefits
Net Present Value (NPV)	\$13 Million	Million	Benefits - Costs

2. Discussion

The integration of GIS, IoT, remote sensing, and the Random Forest machine learning model demonstrate measurable improvements for climate-resilient urban forestry management. The proposed framework enabled intelligent tree species selection, predictive growth analysis, and real-time environmental monitoring using multi-source geospatial and environmental datasets. The integration of AI-driven analytics improved decision-making for site suitability analysis, adaptive maintenance, and urban ecosystem management.

The study also identified several implementation challenges, including data quality inconsistencies, limited access to environmental datasets, and computational requirements for large-scale spatial analysis. Despite these limitations, the integration of AI, GIS, and IoT technologies provides an effective

approach for improving urban climate resilience, environmental sustainability, and long-term urban forestry planning.

V. CONCLUSIONS

The current study confirms that the integration of GIS, IoT, remote sensing, and AI provides a transformative approach to urban forestry and climate resilience. The pilot implementations in Sukabumi and Bogor demonstrated measurable outcomes, including up to 20% improvement in tree survival, urban cooling of up to 2 °C, improved air quality, and a 10% reduction in maintenance costs. These findings highlight the effectiveness of technology-driven and adaptive urban forestry management for supporting sustainable urban planning and environmental resilience. The research contributes to the existing literature through the development of an integrated geospatial-IoT-AI framework, the application of machine learning for predictive urban forestry analysis, and the validation of climate-resilient tree planting strategies through pilot case studies.

Despite these promising results, several challenges remain, including data standardization, integration of heterogeneous GIS and IoT datasets, computational requirements, and implementation costs in resource-limited urban environments. Future research should focus on expanding pilot implementations across diverse urban contexts, improving predictive spatial analytics, strengthening ethical and policy frameworks for AI adoption, and enhancing stakeholder collaboration in smart urban forestry systems. Continuous advancements in AI-driven environmental monitoring and adaptive management will further support the development of sustainable and climate-resilient urban ecosystems.

ACKNOWLEDGEMENT

We express our deepest gratitude to all those who contributed to this research. We extend our sincere appreciation to Nusa Putra University. We also acknowledge the insightful discussions and feedback from our colleagues, which have significantly enhanced this study. Our heartfelt gratitude goes to our families for their unwavering support and encouragement throughout this journey. Additionally, we thank the institutions and organizations that provided resources and research support, fostering academic advancement in urban forestry

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