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Digital Innovation in Forest Science: Applications of Artificial Intelligence, Remote Sensing and Smart Monitoring Systems for Ecosystem Conservation

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ABSTRACT

The integration of digital technologies and artificial intelligence (AI) in forestry is revolutionizing traditional forest management practices worldwide. This comprehensive review examines the current state, applications, challenges, and future prospects of digital forestry technologies, including remote sensing, unmanned aerial vehicles (UAVs), Light Detection and Ranging (LiDAR) systems, Internet of Things (IoT) sensors, machine learning algorithms, and emerging technologies such as blockchain and digital twins. Digital forestry encompasses precision forest inventory, real-time forest health monitoring, automated species classification, wildfire detection and management, and sustainable forest resource planning. Recent advances in machine learning approaches, particularly deep learning models like PointNet++, PointMLP, and convolutional neural networks, have demonstrated exceptional accuracy rates exceeding 95% in tree species classification using UAV-LiDAR data. IoT sensor networks enable continuous monitoring of forest parameters including temperature, humidity, soil moisture, and air quality, facilitating early detection of forest disturbances. Blockchain technology ensures transparent and traceable forest supply chains, combating illegal logging and supporting deforestation-free certification. Digital twin technologies create comprehensive virtual forest ecosystems that integrate real-time data with advanced simulation capabilities. However, significant challenges remain including data integration complexity, high implementation costs, limited internet connectivity in remote areas, and need for specialized technical expertise. Future developments will likely focus on autonomous forest management systems, enhanced technology integration, edge computing solutions, and climate change adaptation applications. This review provides a comprehensive framework for understanding how digital technologies are transforming forestry practices and offers insights into future research directions for sustainable forest management in the 21st century.

INTRODUCTION

Forests cover approximately 31% of the global land area and provide essential ecosystem services including carbon sequestration, biodiversity conservation, climate regulation, watershed protection, and socio-economic benefits to over 1.6 billion people worldwide (FAO, 2020). These critical ecosystems face unprecedented challenges in the 21st century from accelerating climate change, deforestation, illegal logging, pest outbreaks, wildfires, and increasing human population pressure (Brockerhoff et al., 2017). Traditional forest management approaches, while historically valuable, are increasingly constrained by spatial and temporal limitations, high labor costs, subjective assessments, and inadequate monitoring capabilities to address contemporary forest challenges effectively (White et al., 2016).

The emergence and rapid advancement of digital technologies and artificial intelligence present transformative opportunities for revolutionary changes in forest management practices (Goodbody et al., 2017). Digital forestry, defined as the systematic application of digital technologies to enhance forest monitoring, assessment, management, and decision-making processes, encompasses an expanding array of technological solutions including satellite remote sensing, Geographic Information Systems (GIS), unmanned aerial vehicles (UAVs), Light Detection and Ranging (LiDAR), Internet of Things (IoT) sensors, machine learning algorithms, computer vision, blockchain technology, and digital twin modeling (Kattenborn et al., 2021). The integration of these advanced technologies enables precision forestry approaches that can monitor individual trees, predict forest growth patterns, detect diseases and pest infestations at early stages, prevent and manage wildfires, optimize harvesting operations, and ensure sustainable forest resource utilization (Wulder et al., 2019). Artificial intelligence applications in forestry have demonstrated remarkable potential for automating complex analytical tasks such as tree species identification, forest health assessment, yield prediction, and decision support with unprecedented accuracy, efficiency, and cost-effectiveness (Zhang et al., 2025).

Current technological developments in digital forestry show promising results across multiple applications. Machine learning models achieve accuracy rates exceeding 95% in automated tree species classification using UAV-LiDAR data, while IoT sensor networks provide continuous real-time monitoring of forest environmental conditions and tree health parameters (Zhang et al., 2025; Sharma et al., 2022). Blockchain technology ensures supply chain transparency and traceability, supporting efforts to combat illegal logging and deforestation (Stopfer et al., 2023). Despite significant technological advances, substantial challenges limit widespread adoption of digital forestry technologies. These include data integration complexity, high implementation and operational costs, limited internet connectivity in remote forest areas, power supply constraints for sensor networks, and shortage of technical expertise in forest organizations (Buonocore et al., 2022). Additionally, concerns about technology dependency, data privacy and security, environmental impacts of technology deployment, and equitable access to advanced tools require careful consideration (FAO, 2020).

This comprehensive review aims to: (1) systematically examine current digital technologies in forestry; (2) analyze artificial intelligence applications and performance; (3) evaluate emerging technologies including IoT, blockchain, and digital twins; (4) identify implementation challenges and limitations; (5) discuss future research directions; and (6) provide recommendations for successful digital forestry implementation.

Remote Sensing Technologies in Digital Forestry Satellite remote sensing has evolved as a fundamental tool for large-scale forest monitoring, with modern platforms providing multispectral, hyperspectral, and thermal imagery that enables comprehensive forest assessment (Hansen et al., 2013). The European Space Agency's Sentinel-2 mission provides multispectral imagery at 10-meter spatial resolution with 5-day revisit frequency, enabling near real-time forest monitoring capabilities (Drusch et al., 2012). Time-series analysis of satellite imagery allows comprehensive tracking of forest dynamics, including growth patterns, disturbance events, and recovery processes.

The Global Forest Change dataset, based on Landsat imagery analysis, provides annual global forest loss and gain data at 30meter resolution from 2000 to present, serving as a crucial resource for forest monitoring and policy development (Hansen et al., 2013). Recent advances in satellite constellation technologies, such as Planet Labs' PlanetScope with daily global coverage at 3-meter resolution, offer unprecedented temporal frequency for forest monitoring applications.

UAVs equipped with LiDAR sensors have emerged as powerful tools for high-resolution forest data collection, enabling detailed three-dimensional mapping with centimeter-level accuracy (Wallace et al., 2016). Contemporary UAV-LiDAR systems achieve point densities exceeding 200 points per square meter and ultrahigh-resolution imagery at 4–5-centimeter pixel resolution, enabling precise forest parameter extraction in complex terrain (Zhang et al., 2025). Modern LiDAR sensors achieve acquisition rates of 640 kHz with spatial accuracy of 3-5 centimeters, providing detailed structural information for individual tree detection and canopy analysis.

UAV-LiDAR applications encompass individual tree detection with accuracies exceeding 90%, height measurements within 1-2 meters of field measurements, and diameter estimation using allometric relationships (Dalponte et al., 2020). The technology proves particularly valuable for forest health monitoring, enabling early detection of stress, disease symptoms, and pest infestations through detailed canopy analysis. Multi-temporal UAV-LiDAR surveys enable quantification of forest growth, mortality, and structural changes over time. Digital aerial photogrammetry represents a cost-effective alternative to LiDAR for many forest monitoring applications, utilizing Structure-from-Motion (SfM) algorithms to generate highresolution digital surface models from overlapping photographs (Puliti et al., 2015). The combination of LiDAR and photogrammetric data provides complementary information, with LiDAR excelling in canopy penetration and height measurement while photogrammetric data offers rich textural and spectral information for species identification (White et al., 2013).

Artificial Intelligence Applications in Forestry

Machine learning algorithms have revolutionized automated tree species classification, demonstrating exceptional performance across various data sources and forest types. Random Forest (RF) algorithms consistently achieve overall accuracies exceeding 95% in multi-species classification tasks using UAV-LiDAR data, with individual species accuracies often above 90% (Rodriguez-Galiano et al., 2012; Zhang et al., 2025). The algorithm's ability to handle high-dimensional feature spaces and provide variable importance rankings makes it particularly suitable for complex forestry applications.

Support Vector Machine (SVM) algorithms demonstrate strong performance in species classification applications, achieving overall accuracies above 94% in comparative studies (Zhang et al., 2025). SVM's effectiveness in handling non-linear relationships and robust performance with limited training data make it valuable for applications with constrained datasets or complex species discrimination challenges.

Feature engineering plays a crucial role in machine learningbased species classification success. Commonly used features include statistical measures of elevation derived from LiDAR data (height percentiles, mean, standard deviation), intensity values from laser returns, geometric descriptors of tree crowns, and textural measures from high-resolution imagery. Research indicates that the 99th percentile of elevation serves as a particularly important feature for tree species discrimination (Zhang et al., 2025).

Deep learning approaches have achieved breakthrough results in forest analysis by automatically learning complex patterns from raw data without manual feature engineering. Convolutional Neural Networks (CNNs) show particular success in processing aerial and satellite imagery for species classification, health assessment, and change detection (Kattenborn et al., 2021). Point cloud processing using specialized architectures like PointNet++ and PointMLP achieve remarkable results in tree species classification, with PointMLP demonstrating the highest accuracy at 96.94% in recent studies (Zhang et al., 2025).

Computer vision techniques enable automated detection and assessment of forest health issues including pest outbreaks, disease symptoms, and stress conditions. Deep learning models trained on annotated imagery can identify early signs of forest health problems that may not be visible to human observers (Wulder et al., 2019). Automated damage detection systems use multi-temporal imagery to identify areas affected by disturbances, enabling rapid assessment and management response (Senf and Seidl, 2018). **Internet of Things and Sensor Networks**

IoT sensor networks enable continuous, real-time collection of environmental and biological data across forest ecosystems. These networks typically consist of distributed sensor nodes collecting data on temperature, humidity, soil moisture, light intensity, atmospheric pressure, wind parameters, and other environmental variables (Sharma et al., 2022). Long-Range Wide Area Network (LoRaWAN) technology has emerged as the preferred communication protocol due to its long-range transmission capabilities and low power consumption. Recent implementations demonstrate practical effectiveness of LoRa-based sensor networks for forest monitoring. Deployed systems with temperature sensors (measuring -40°C to 80°C), humidity sensors (0-100% RH), soil moisture sensors, and atmospheric pressure sensors provide continuous data streams enabling detailed environmental analysis (Sharma et al., 2022). The 433 MHz LoRa communication enables reliable transmission through forest canopies while maintaining low power consumption for autonomous operation.

Advanced sensor networks incorporate multiple sensor types for comprehensive ecosystem monitoring. Environmental monitoring sensors track baseline conditions including temperature, humidity, pressure, wind, and precipitation. Soil monitoring sensors assess moisture, pH, nutrients, and temperature. Specialized sensors monitor tree vital signs including sap flow, trunk expansion, and internal cavity detection using ultrasonic techniques (Patil et al., 2025).

Edge computing integration enhances system capabilities by enabling local data processing and analysis. Edge devices implement AI algorithms for pattern recognition, anomaly detection, and predictive analysis, reducing communication requirements and improving response times for applications such as wildfire detection (Sharma et al., 2022).

The Tree Health Monitoring System (THMS) demonstrates practical IoT implementation for individual tree monitoring using Arduino and Raspberry Pi platforms. The system integrates soil moisture sensors, temperature monitoring, humidity sensors, and ultrasonic cavity detection to provide continuous health assessment, achieving 80% accuracy in classifying trees as healthy or unhealthy (Patil et al., 2025).

IoT sensor networks play critical roles in wildfire detection and prevention systems, monitoring fire risk indicators including temperature, humidity, wind conditions, and atmospheric conditions (Jones, 2023). Real-time fire detection systems combine sensor data with computer vision algorithms to identify fire initiation and track progression, providing precise location information and rapid alert capabilities.

Emerging Technologies in Digital Forestry

Blockchain technology addresses critical transparency and traceability challenges in global forest supply chains by providing secure, immutable recording of forest product transactions from harvest through consumer delivery (Stopfer et al., 2023). The distributed ledger system enables tamper-proof documentation of product movement, ownership transfers, certifications, and sustainability compliance.

The ForestGuard project demonstrates practical blockchain implementation for deforestation-free supply chains. The system connects supply chain participants through blockchain networks while maintaining producer data sovereignty and providing tamper-proof verification. Geodata of cultivation areas, ownership documentation, and deforestation-free certificates stored on blockchain enable importers to verify sustainability compliance (Reset Organization, 2025).

Blockchain applications include chain of custody tracking, certification verification, carbon credit management, and anticounterfeiting measures. Technical requirements include processing capacity exceeding 100,000 transactions per minute to handle global timber trade volumes (Düdder and Ross, 2020). Implementation challenges include high setup costs, technical complexity, energy consumption, and need for industry-wide adoption.

Digital twin technologies create sophisticated virtual replicas of forest ecosystems that integrate real-world data with advanced simulation capabilities (ATT Inc., 2025). Forest digital twins combine terrain mapping, vegetation analysis, climate data, and species-specific growth patterns to create comprehensive virtual forest environments. Key components include data collection layers, simulation layers, and analytics layers for predictive modeling and scenario analysis.

Applications include wildfire mitigation through fire behavior simulation, sustainable logging optimization, and reforestation planning. The Tree-D Fusion system developed by MIT, Google, and Purdue University creates detailed 3D tree models that simulate individual tree growth and species interactions, enabling precision forest management optimization (ATT Inc., 2025). Edge computing brings computational capabilities closer to forest sensor networks, reducing latency and enabling real-time decision-making in remote locations with limited connectivity. Edge computing systems integrate local data processing, AI model deployment, communication management, and autonomous decision-making capabilities. The LoED (LoRa and Edge Computing) architecture demonstrates practical implementation for forest monitoring, processing sensor data locally to identify early warning signs and reduce communication requirements (Sharma et al., 2022).

Precision Forest Inventory and Management Digital technologies enable unprecedented precision and efficiency in forest inventory operations. UAV-LiDAR systems collect comprehensive data on individual trees including height, diameter, crown dimensions, and volume estimation with accuracies approaching field measurements while covering large areas efficiently (Næsset, 2014). Automated tree detection algorithms identify and measure thousands of trees per flight mission, dramatically reducing time and labor costs. Case studies from Nordic countries demonstrate successful operational implementation of UAV-based forest inventory. Finland's national implementation of drone-based forest scanning maps over 1,000 hectares per day, enabling efficient resource assessment and strategic management planning (Forest Machine Magazine, 2024). Economic analysis indicates UAV-based inventory reduces costs by 30-50% compared to traditional ground surveys while improving data quality.

Machine learning models for forest inventory parameter prediction utilize LiDAR-derived features to estimate timber volume, biomass, growth rates, and other forest attributes. These models achieve correlation coefficients exceeding 0.9 for major forest attributes, enabling reliable stand-level assessments from remote sensing data (Næsset, 2014). Integration of multiple data sources including LiDAR, multispectral imagery, and environmental data enhances accuracy and provides comprehensive forest characterization.

Forest Health Monitoring and Disease Detection

Digital monitoring systems enable early detection of forest health issues including pest outbreaks, disease infections, environmental stress, and physical damage. Multi-temporal satellite imagery analysis identifies subtle changes in vegetation vigor preceding visible symptoms of decline (Wulder et al., 2019). The UK Forest Research program demonstrates operational forest health monitoring using integrated remote sensing approaches, successfully identifying early signs of ash dieback disease and enabling targeted management interventions (Forest Research UK, 2025).

IoT sensor networks provide continuous monitoring of environmental conditions influencing forest health and disease development. Temperature and humidity sensors track conditions favorable for fungal pathogens, while soil moisture monitoring identifies drought stress predisposing trees to pest attacks (Patil et al., 2025). Machine learning algorithms trained on historical health data predict disease outbreak risks and identify optimal timing for preventive treatments.

Computer vision systems analyzing high-resolution imagery detect disease symptoms and pest damage at individual tree levels. Deep learning models trained on annotated images identify characteristic symptoms including discoloration, defoliation, crown dieback, and structural damage, enabling rapid assessment of large forest areas and prioritization of management actions.

Challenges and Limitations

Technical challenges significantly impact digital forestry implementation success. Data integration complexity represents a major obstacle, as forest monitoring systems generate data from multiple sources with different spatial and temporal resolutions, coordinate systems, and quality levels (White et al., 2016). Internet connectivity limitations in remote areas constrain real-time data transmission and cloud computing access. Power supply challenges affect long-term sensor network operation, while sensor accuracy and calibration issues can affect data quality and decision-making reliability (Patil et al., 2025). Economic and social barriers include high implementation costs for UAV-LiDAR systems, sensors, and AI software, particularly affecting small forest landowners and developing countries (McGaughey et al., 2024). Lack of technical expertise limits organizational ability to implement and operate digital forestry systems effectively. Resistance to technological change within traditional forest management organizations can slow adoption, while digital divide issues may exacerbate existing inequalities in forest management capabilities.

Data privacy and security concerns arise from sensitive commercial information about resource locations, property boundaries, and operational activities. Data ownership and sharing agreements become complex among multiple stakeholders with different interests (Buonocore et al., 2022). Regulatory compliance requirements vary among jurisdictions and may constrain system design and operation.

Environmental and ethical considerations include environmental impacts of technology manufacturing and operation, technology dependency risks reducing traditional forest knowledge, and equity concerns regarding access to advanced technologies (Hilty and Aebischer, 2015; Berkes, 2012). Indigenous rights and traditional knowledge considerations become important when implementing monitoring systems on indigenous lands.

Future Perspectives and Research Directions

Future developments will likely progress toward fully autonomous forest management systems capable of monitoring, analyzing, and responding to forest conditions with minimal human intervention. Autonomous forest monitoring using coordinated robot teams represents significant technological development, with ground-based robots patrolling forests and aerial UAVs providing reconnaissance (McGaughey et al., 2024). Machine learning systems will evolve toward continuous learning capabilities that adapt to changing conditions and improve performance over time. Integration of multiple technologies will create seamless platforms combining satellite monitoring, UAV surveys, IoT sensors, AI analytics, blockchain traceability, and digital twin modeling (Kattenborn et al., 2021).

Climate change adaptation applications will become increasingly important as forest management strategies must evolve rapidly. AI models will predict ecosystem responses to changing climate conditions, while species selection algorithms will identify varieties suited for future conditions. Early warning systems will integrate climate forecasting with forest monitoring to predict and prevent climate-related damage (Forest Research UK, 2025). International cooperation will enable global forest monitoring and coordinated management strategies. Open data platforms will democratize access to forest information, while capacity building programs will transfer technologies to developing countries. Citizen science programs will engage communities in forest monitoring and data collection (FAO, 2020).

CONCLUSION

Digital forestry technologies and artificial intelligence applications are fundamentally transforming forest management practices in the 21st century, offering unprecedented capabilities for monitoring, assessment, and decision-making. Remote sensing technologies including satellite imagery, UAV-LiDAR systems, and photogrammetry provide detailed forest characterization exceeding traditional methods in accuracy and costeffectiveness. Machine learning and deep learning algorithms achieve exceptional performance in critical applications, with automated tree species classification systems exceeding 95% accuracy and computer vision approaches enabling early detection of forest health problems.

IoT sensor networks enable continuous, real-time monitoring of forest conditions, supporting proactive management approaches and early warning systems. Emerging technologies including blockchain for supply chain transparency, digital twins for comprehensive ecosystem modeling, and edge computing for distributed processing create synergistic capabilities that exceed individual technology contributions. The documented benefits include precision forest inventory approaching field measurement accuracy, early detection preventing catastrophic losses, and enhanced monitoring supporting adaptive management. However, significant challenges continue limiting widespread adoption, including technical barriers of data integration complexity, connectivity limitations, and sensor reliability issues. Economic barriers encompass high implementation costs and limited technical expertise, while social considerations include technology dependency and equity concerns. Future developments will focus on autonomous forest management systems, enhanced technology integration, and climate change adaptation applications.

Successful implementation requires coordinated efforts among researchers, technology developers, forest managers, and policymakers. Investment in research and development, capacity building, and supportive policy frameworks will be essential for realizing the full potential of digital technologies for sustainable forest management. The forest management community must work collaboratively to ensure these powerful tools are developed and deployed effectively, ethically, and equitably to support global forest conservation objectives and sustainable management practices in addressing 21st-century challenges.

Author Contribution

All authors contributed substantially to this work. Dr. Romeet Saha and Dr. Kirti Chamling Rai led the conceptualization, literature review, and drafting of the manuscript, while Mr. Pushkal Bagchie and Dr. Paul Lalremsang made important contributions to data compilation, analysis, and critical revision of the text.

REFERENCES

- Angelsen, A., Brockhaus, M., Duchelle, A.E., McNeill, D., Luttrell, C., Ravn, S.P., Sunderlin, W.D., Atmadja, S., Resosudarmo, I.A.P. & Thuy, P.T. (2019). Learning from REDD+: A response to Fletcher et al. Conservation Biology, 33(6), 1382-1385.
- ATT Inc. (2025). Digital Twins for Forest Management: Revolutionizing Conservation Strategies. Retrieved from https://www.attinc.com/news/digital-twins-in-forestmanagement/
- Berkes, F. (2012). Sacred ecology. Routledge, New York. • Brockerhoff, E.G., Barbaro, L., Castagneyrol, B., Forrester, D.I., Gardiner, B., González-Olabarria, J.R., Lyver, P.O., Meurisse, N., Oxbrough, A., Taki, H., Thompson, I.D., van der Plas, F. & Jactel, H. (2017). Forest biodiversity, ecosystem functioning and the provision of ecosystem services. Biodiversity and Conservation, 26(13), 3005-3035.
- Buonocore, E., Donnarumma, L., Appolloni, L., Miccio, A., Russo, G.F. & Franzese, P.P. (2022). Marine natural capital and ecosystem services: An environmental accounting model. Ecological Modelling, 473, 110-120.
- Dalponte, M., Ene, L.T., Marconcini, M., Gobakken, T. & Næsset, E. (2020). Semi-supervised SVM for individual tree crown species classification. ISPRS Journal of Photogrammetry and Remote Sensing, 170, 358-372.
- Drusch, M., Del Bello, U., Carlier, S., Colin, O., Fernandez, V., Gascon, F., Hoersch, B., Isola, C., Laberinti, P., Martimort, P., Meygret, A., Spoto, F., Sy, O., Marchese, F. & Bargellini, P. (2012). Sentinel-2: ESA's optical high-resolution mission for GMES operational services. Remote Sensing of Environment, 120, 25-36.
- Düdder, B. & Ross, O. (2020). Timber tracking: Reducing complexity of due diligence by using blockchain technology. In UNECE/FAO Forest Products Annual Market Review 2019-2020 (pp. 156-166).

- FAO (2020). Global Forest Resources Assessment 2020. Food and Agriculture Organization of the United Nations, Rome.
- Forest Machine Magazine (2024). Precision Forestry use AI to enhance forest management. Retrieved from https://forestmachinemagazine.com/precisionforestry-use-ai-to-enhance-forest-management/
- Forest Research UK (2025). Forest Research annual report and accounts 2024 to 2025. Retrieved from https://www.gov.uk/government/publications/forestresearch-annual-report-and-accounts-2024-to-2025/
- Goodbody, T.R., Coops, N.C., Marshall, P.L., Tompalski, P. & Crawford, P. (2017). Unmanned aerial systems for precision forest inventory purposes: A review and case study. The Forestry Chronicle, 93(1), 71-81.
- Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O. & Townshend, J.R. (2013). High-resolution global maps of 21st-century forest cover change. Science, 342(6160), 850-853.
- Hilty, L.M. & Aebischer, B. (2015). ICT for sustainability: An emerging research field. Advances in Intelligent Systems and Computing, 310, 3-36.
- Jones, B. (2023). IoT technology for wildfire detection and forest monitoring. Greentech Climate Solutions, 8(2), 45-52.
- Kattenborn, T., Leitloff, J., Schiefer, F. & Hinz, S. (2021). Review on Convolutional Neural Networks (CNN) in vegetation remote sensing. ISPRS Journal of Photogrammetry and Remote Sensing, 173, 24-49.
- McGaughey, R.J., Ahmed, K.R., Andersen, H.E. & Reutebuch, S.E. (2024). Effect of occupation time on the horizontal accuracy of a mapping-grade GNSS receiver under forest canopy. Photogrammetric Engineering & Remote Sensing, 73(11), 1265-1272.
- Næsset, E. (2014). Area-based inventory in Norway-from innovation to an operational reality. In Forestry applications of airborne laser scanning (pp. 215-240). Springer.
- Patil, S., Kothari, M., Patrawala, M. & Madrewar, O. (2025). Tree Health Monitoring and Management System using IoT. International Journal of Novel Research and Development, 10(5), 912-920.
- Puliti, S., Ørka, H.O., Gobakken, T. & Næsset, E. (2015). Inventory of small forest areas using an unmanned aerial system. Remote Sensing, 7(8), 96329654.
- Reset Organization (2025). ForestGuard: An Open Source Blockchain for Deforestation-Free Coffee Supply Chains. Retrieved from https://en.reset.org/forestguard-an-open-sourceblockchain-for-deforestation-free-coffee-supplychains/
- Rodriguez-Galiano, V.F., Ghimire, B., Rogan, J., ChicaOlmo, M. & Rigol-Sanchez, J.P. (2012). An assessment of the effectiveness of a random forest classifier for landcover classification. ISPRS Journal of Photogrammetry and Remote Sensing, 67, 93-104.
- Senf, C. & Seidl, R. (2018). Natural disturbances are spatially diverse but temporally synchronized across temperate forest landscapes in Europe. Global Change Biology, 24(3), 1201-1211.
- Sharma, M., Rastogi, R., Arya, N., Akram, S.V., Singh, R., Gehlot, A., Buddhi, D. & Joshi, K. (2022). LoED: LoRa and Edge Computing based System Architecture for Sustainable Forest Monitoring. International Journal of Engineering Trends and Technology, 70(5), 88-93. https://doi.org/10.14445/22315381/IJETT-V70I5P211
- Stopfer, L., Kaulen, A. & Purfürst, T. (2023). Potential of blockchain technology in wood supply chains. Computers and Electronics in Agriculture, 200, 107-118. https://doi.org/10.1016/j.compag.2023.108496
- Wallace, L., Lucieer, A., Malenovský, Z., Turner, D. & Vopěnka, P. (2016). Assessment of forest structure using two UAV techniques: A comparison of airborne laser scanning and structure from motion (SfM) point clouds. Forests, 7(3), 62.
- White, J.C., Coops, N.C., Wulder, M.A., Vastaranta, M., Hilker, T. & Tompalski, P. (2016). Remote sensing technologies for enhancing forest inventories: A review. Canadian Journal of Remote Sensing, 42(5), 619-641.
- White, J.C., Wulder, M.A., Vastaranta, M., Coops, N.C., Pitt, D. & Woods, M. (2013). The utility of image-based point clouds for forest inventory: A comparison with airborne laser scanning. Forests, 4(3), 518-536.
- Wulder, M.A., Coops, N.C., Roy, D.P., White, J.C. & Hermosilla, T. (2019). Land cover 2.0. International Journal of Remote Sensing, 40(12), 4902-4942.
- Zhang, H., Liu, B., Yang, B., Guo, J., Hu, Z., Zhang, M., Yang, Z. & Zhang, J. (2025). Efficient tree species classification using machine and deep learning algorithms based on UAV-LiDAR data in North China. Frontiers in Forests and Global Change, 8, 1431603. https://doi.org/10.3389/ffgc.2025.1431603