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Silviculture in the Digital Age: A Review of LiDAR-Based Forest Management

T. K. Pawar, P. R. Kolhe, V. D. Tripathi, K. D. Bhuwad, V. D. Jadhav

P. G. scholar, Department of Silviculture and Agroforestry , College of Forestry, Dr. Balasaheb Sawant Konkan Krushi Vidhyapeeth, Dapoli, Ratnagiri, Maharastra, India.

Associate Professor, College of Agriculture Engineering and Technology, Dr. Balasaheb Sawant Konkan Krushi Vidhyapeeth, Dapoli, Ratnagiri, Maharastra, India.

Assistant Professor, Department of Silviculture and Agroforestry , College of Forestry, Dr. Balasaheb Sawant Konkan Krushi Vidhyapeeth, Dapoli, Ratnagiri, Maharastra, India.

P. G. scholar, Department of Vegetable Science , College of Horticulture, Dr. Balasaheb Sawant Konkan Krushi Vidhyapeeth, Dapoli, Ratnagiri, Maharastra, India.

IT Professional, College of Agriculture Engineering and Technology, Dr. Balasaheb Sawant Konkan Krushi Vidhyapeeth, Dapoli, Ratnagiri, Maharastra, India.

ABSTRACT: The integration of hyperspectral imagery (HSI) and LiDAR technology is revolutionizing environmental monitoring. HSI captures detailed spectral info, while LiDAR provides precise 3D structural measurements, offering insights into vegetation structure and composition. This combination overcomes multispectral imaging limitations, shifting research from traditional surveys to advanced methods. The forestry sector is adopting technologies like ICT and AI to improve efficiency, with LiDAR remote sensing showing great promise for precise forest management. LiDAR data can detect individual trees with 87.2% accuracy, identifying 94.8% of tree positions. Forests play a crucial role in climate change mitigation, providing ecosystem services like biodiversity conservation, recreation, and timber. Sustainable forest management is needed to balance ecology and economy. Backpack LiDAR is a portable tool for collecting high-resolution point cloud data, enabling researchers to extract tree structure info, create 3D models, and estimate above-ground biomass. Combining backpack LiDAR with UAV multispectral data improves carbon storage estimates. LiDAR technology has various applications in silviculture, including carbon stock and biomass estimation, forest inventory, and monitoring deforestation. It also aids forest management, biodiversity conservation, wildlife habitat mapping, and wildfire management. The SFI SmartForest program in Norway is using LiDAR to digitize forestry, improving productivity and reducing environmental impact.

KEYWORDS: LiDAR technology, Silviculture, Environmental monitoring, Forest management, Biomass estimation.

I. INTRODUCTION

The combination of hyperspectral imagery (HSI) and LiDAR technology is advancing environmental monitoring. HSI captures detailed wavelength info, while LiDAR provides precise 3D structural measurements. Together, they offer detailed insights into vegetation structure and composition, overcoming limitations of multispectral imaging. This tech combo is shifting vegetation research from traditional surveys to more advanced, indirect methods, enabling deeper analysis beyond just forest types and growth patterns. The forestry sector is seeing increased demand for technologies like ICT and AI to improve efficiency. LiDAR remote sensing is one such tech showing great promise for precise forest management. LiDAR data to detect individual trees with 87.2% accuracy, identifying 94.8% of tree positions by dividing data into height intervals and applying advanced algorithms. Forests play a key role in reducing climate change by storing carbon and supporting ecosystems. They provide benefits like biodiversity, recreation, and timber, absorbing CO_2 through growth and soil accumulation. Forest management practices like thinning, rotation, and species selection impact carbon storage. To maximize these benefits, sustainable management is needed, balancing ecology and economy.

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Backpack LiDAR is a portable and adaptable tool that quickly collects high-resolution point cloud data in forests, offering a new way to survey forest resources. Researchers have used it to extract tree structure info, create 3D models, and estimate above-ground biomass. Combining backpack LiDAR with UAV multispectral data improves carbon storage estimates. It's also effective in filling gaps in UAV-LiDAR data, especially in lower forest stand areas, providing comprehensive tree parameter info. Studies have shown that backpack LiDAR systems with SLAM algorithms achieve high-precision measurements of forest parameters like DBH. Recent advancements include multi-sensor fusion SLAM and dual-LiDAR devices, improving forest vertical structure parameter extraction and addressing GNSS signal issues under forest canopies.

II. LIDAR TECHNOLOGY

LiDAR, or laser altimetry, is a technique used to measure vegetation. It works by sending a laser pulse from an aircraft or satellite to the Earth's surface, where it bounces off leaves, branches, and other canopy materials. The reflected energy is collected by a telescope, and the time it takes for the pulse to return is used to calculate various metrics about the vegetation structure (Muley *et al.,* 2025).

LiDAR, or 3D laser scanning, is an active remote sensing system that uses laser signals to measure distances. It sends laser pulses to the ground, which bounce off objects like buildings and trees, and returns to the LiDAR system. By measuring the time it takes for the pulse to return, the system calculates the distance traveled and converts it into elevation data. The LiDAR system uses components like GPS for location and an inertial measurement unit (IMU) for orientation to calculate the 3D position of objects. The data is stored in formats like LAS and LAZ, which compress data efficiently and support spatial analysis. These formats also store metadata like point classification and color info for further analysis.

III. SOURCE OF LIDAR DATA

LiDAR data is available from various sources, including public and private providers, often at different costs. When getting LiDAR data, consider factors like format, projection, datum, classification, and usability to ensure it works with your tools and software. Sources include USGS Earth Explorer, NOAA, Open Topography, and local agencies. You can also collect data using drones with LiDAR sensors for detailed mapping, but be aware of limitations like range and accuracy. When using drones, consider stability, payload capacity, flight time, GPS accuracy, and laser scanner quality. Using ground control points (GCPs) and planning for vegetation and topography can improve data accuracy. These specs matter because they affect data quality, accuracy, and usefulness. For example, format and projection impact analysis and visualization, while datum affects accuracy relative to the Earth's surface. Classification helps differentiate point cloud features like vegetation or buildings. Considering these factors ensures you get suitable LiDAR data for your project.

IV. APPLICATION OF LIDAR IN SILVICULTURE

Carbon stock and biomass estimation: - Forests play a vital role in absorbing carbon, making accurate biomass measurement crucial for climate studies and carbon credit programs. LiDAR technology significantly improves biomass estimation and carbon stock assessment by analyzing tree height, crown shape, and vegetation density to estimate above-ground biomass. This data helps model forest carbon storage and predict how forests respond to environmental changes. Research shows LiDAR-based estimation is more accurate than traditional methods, especially in complex ecosystems (Dubayah and Drake, 2000).

Forest inventory: - LiDAR technology is also used for forest inventory, which involves collecting data on tree species, volume, biomass, and canopy cover. Unlike traditional methods that sample small areas and extrapolate, LiDAR provides accurate estimates of tree height, diameter, and crown size. This makes it a valuable tool for sustainable forest management and conservation planning; with research showing LiDAR-based inventories can be more accurate than manual methods.

Illegal deforestation is a significant global issue, causing biodiversity loss and increased carbon emissions. While satellite imagery can detect large-scale deforestation, it often misses smaller disturbances. LiDAR technology fills this gap by capturing detailed changes in forest structure over time. Spaceborne LiDAR missions like NASA's GEDI are now tracking forest changes worldwide, supporting conservation efforts (Peterson *et al.,*2005).

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Forest management: - LiDAR technology allows users to create detailed maps of forest terrain by flying over it. This helps plan activities like road construction, tree management, and fire risk analysis. LiDAR provides data on forest structure, tree height, and density, supporting analysis of tree growth and health. Aerial scanning covers large areas efficiently, saving time and effort compared to ground surveys. The data also supports planning for fire and rescue operations, road construction, and statistical analysis of forest development, including individual tree species. With SLAM technology, scanning is possible without GNSS signals, even under tree canopies. Data recording is flexible, requiring no GNSS receiver or base station, and can be done in-flight or on foot. This makes comprehensive forest scanning more accessible and efficient.

Monitoring biodiversity: - LiDAR technology identifies tree species by analyzing unique features like crown shape, foliage density, and branching patterns, helping map species distribution in forests. This is valuable for biodiversity conservation, as knowing species composition helps protect endangered ecosystems. Combining LiDAR with hyperspectral imaging improves species classification, allowing conservationists to track changes and detect invasive species. LiDAR technology is improving wildlife habitat mapping, essential for conservation and ecosystem restoration. By analyzing forest structure, canopy cover, and topography, researchers can identify key habitat characteristics supporting various species. LiDAR detects subtle vegetation differences, indicating nesting sites, foraging areas, and sheltering zones. Accurate habitat mapping enables conservationists to prioritize areas for protection, restoration, or enhancement. LiDAR data also helps monitor wildlife population changes, evaluate conservation effectiveness, and track ecosystem resilience to environmental stressors (Akay *et al.,* 2008).

Management of wildfire: - Forest fires are a major concern worldwide, and understanding how they behave is key to reducing risks and improving response strategies. LiDAR technology helps fire management by creating detailed maps of fuel loads, canopy gaps, and vegetation density, which affect fire spread and intensity. Studies show LiDAR-based fuel maps are more accurate than traditional assessments, leading to better fire risk modelling and suppression strategies (Peterson *et al.,*2005).

Smart forest (SFI):- The SFI SmartForest program aims to make Norway's forestry sector a leader in digitization by 2028. To achieve this, they're using LiDAR technology to improve productivity and reduce environmental impact. They needed a solution that was versatile and provided precise measurements, so they chose a handheld mobile mapping system. This allowed them to quickly scan dense terrain, collecting accurate data and creating point cloud models to analyze wood quality and biomass. The system was more efficient than TLS and more effective than UAVs in thick vegetation. SFI SmartForest will continue using the mobile scanner for deep learning research, creating accurate point clouds to inform their work.

V. CONCLUSION

The integration of LiDAR technology is transforming forestry and environmental monitoring. By providing detailed 3D structural measurements, LiDAR enables LiDAR to detect individual trees, estimate biomass, and monitor forest health with high accuracy. Its applications in silviculture, conservation, and wildfire management are enhancing sustainable forest practices. As LiDAR technology advances, its potential for improving ecosystem management and climate change mitigation will only grow.

VI. FUTURE THRUST

Advanced data integration: Combining LiDAR with hyperspectral, multispectral, and SAR data for comprehensive ecosystem analysis. Real-time monitoring: Developing systems for near-real-time forest monitoring and alert systems for deforestation, wildfires, or other disturbances. Automated analysis: Leveraging AI and machine learning for automated tree species classification, biomass estimation, and forest health assessment. Under-canopy mapping: Improving SLAM algorithms and multi-sensor fusion for detailed mapping under dense forest canopies. Satellite LiDAR constellations: Launching satellite LiDAR constellations for global forest monitoring and change detection.

REFERENCES

Akay, A. E., Oğuz, H., Karas, I. R., & Aruga, K. (2008). Using LiDAR technology in forestry activities. *Environmental Monitoring and Assessment, 151(1-4),* 117-125.

Dubayah, R., & Drake, J. B. (2000). Lidar remote sensing for forestry. *Journal of Forestry, 98(6),* 44-46.

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Peterson, B., Dubayah, R., Hyde, P., Hofton, M., Blair, J. B., & Fites-Kaufman, J. (2005). Use of LiDAR for forest inventory and forest management applications. *Proceedings of the Seventh Annual Forest Inventory and Analysis Symposium, 3-7*.

Muley, A. S., Sivakumar, B. and Anil, A. S. 2025. LiDAR in Forestry: Advancing Precision in Forest Inventory and Management. Vigyan Varta 6(3): 387-390.

Brodu, N., & Lague, D (2012) 3D terrestrial lidar data classification of complex natural scenes using a multi-scale dimensionality criterion. Applications in geomorphology. *ISPRS Journal of Photogramometry and Remote Sensing, 68,* 121-134

Dassol, M., Constant, T. & Fournier, M. (2011) The Use of Terrestrial LiDAR Technology in Forest science: Application Fields, Benefits and Challenges. *Annals of forest science, 65(5).* 959-974

Pulit, S. Dash, J. P. Watt. M. S. Bresdenbach, J., & Pearse, G D (2020) A comparison of UAV laser scanning, photogrammetry and airborne laser scanning for precision inventory of small-forest properties Forestry. *An International Journal of Forest Research, 93(1),* 150-162.

Wulder. M. A., White, J. C. Nelson, R. I, Næsset, E, Ørka, H. O. Coops, N. C. Hilker. T. Bater. C. W. & Gobakken, T. (2012) Ladar sampling for large-area focest characterization. *A review Remote Sensing of Envirorunent, 121,* 196-209.

Young, A. P, Olsen, M., Driscoll. N. Flick, R., Gutierrez, R., Guza, R. Jolinstone, I., & Kuester, F (2010) Comparison of airborne and terrestrial lidar estimates of seacliff erosion unsouthern California. *Photogrammetric engineering & remote sensing, 7014),* 421-427.

Wikipedia Contributors. (2019, July 8). Simultaneous localization and mapping. Wikipedia, The Free Encyclopedia.

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