Non-Destructive Methods for Estimating Tree Biomass and Volume

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ABSTRACT

Accurate estimation of tree biomass and volume is crucial for forest management, carbon sequestration studies, and ecological research. Traditional methods, such as harvesting and weighing trees, are destructive and impractical for large-scale assessments. Non-destructive methods provide an alternative approach by utilizing allometric equations, remote sensing technologies, and ground-based measurements. Techniques such as laser scanning (LiDAR), photogrammetry, and ground-based dendrometric measurements (e.g., tree height, diameter at breast height, and wood density) enable precise biomass and volume estimation without damaging the tree. This paper reviews various non-destructive methods, highlighting their advantages, limitations, and applications in forestry and environmental monitoring.

INTRODUCTION

Determining the biomass and volume of trees is crucial for effective forest management, ecological research, and carbon sequestration studies. Traditional methods, which often involve felling or destructively sampling trees, can be impractical, particularly when working with large, valuable, or protected forests. As a result, non-destructive techniques for estimating tree biomass and volume have become more prevalent, enabling researchers and foresters to gather critical data while minimizing ecological impact. This article explores some of the most widely used non-destructive approaches for estimating tree biomass and volume. Allometric models, which are statistical relationships that describe how different tree parameters (such as diameter, height, or crown size) are related to biomass and volume. These models are derived from the measurement of tree dimensions and the application of regression analysis to predict biomass or volume based on these variables.

For biomass estimation, allometric equations often utilize diameter at breast height (DBH) or tree height as predictor variables. A common equation might estimate tree biomass as a function of DBH raised to a certain power, adjusted by species-specific constants. Allometric equations are particularly useful for estimating tree biomass because they provide an estimate of the living tissue mass (wood, leaves, branches). Similarly, allometric models for volume estimation often rely on a comparable approach, using DBH and tree height to predict the total volume of a tree. These models can be species-specific or generalized across similar types of forests.

The advantages of using allometric models include their non-invasive and quick application in the field, as well as their suitability for a wide range of tree species. They can provide estimates for individual trees or forest plots. However, these models require reliable species-specific or site-specific data to produce accurate estimates, and they may not be accurate for all three types (Montes *et al*., 2000).

Terrestrial LiDAR: represents a ground-based remote sensing technology that utilizes laser pulses to create accurate 3D point clouds of forest structures. By scanning the tree canopy, trunk, and surrounding environment, LiDAR can produce detailed digital representations of individual trees or entire forest plots.

Biomass Estimation: LiDAR data can facilitate the estimation of tree height, crown volume, and overall canopy structure, which are crucial parameters for biomass estimation. By analysing the point cloud data, researchers can evaluate tree dimensions and derive biomass estimates using allometric models specifically designed for the structural data obtained from LiDAR.

Volume Estimation: LiDAR can be employed directly to determine tree volume by assessing the geometry of the tree's trunk and crown. The point cloud data can be processed to identify the tree trunk, measure its dimensions, and compute its volume.

Advantages: Offers high-resolution, detailed, and precise 3D structural data of trees. Applicable for estimating the biomass and volume of individual trees or entire forest stands. Well-suited for large-scale forest inventories.

Limitations: Involves significant initial costs for equipment and data processing. Requires specialized knowledge to interpret LiDAR data and apply it effectively for biomass and volume estimation.

Terrestrial Photogrammetry and UAVs (Drones) Photogrammetry entails capturing overlapping images of trees or forested regions and utilizing software to transform these images into three-dimensional models. When integrated with UAVs (unmanned aerial vehicles), commonly referred to as drones, this approach facilitates efficient and high-resolution mapping of forest structures.

Biomass Estimation: Similar to LiDAR, photogrammetry can yield detailed insights into tree height, canopy structure, and tree density. These parameters can be applied in allometric equations to estimate biomass.

Volume Estimation: By processing images to generate 3D models of individual trees or forest plots, photogrammetry can assess the volume of trees based on their dimensions. Drones equipped with cameras can o survey extensive areas, rendering this technique particularly advantageous for monitoring large forested regions.

Advantages: Cost-effective and relatively straightforward to implement. Effective for surveying large, hard-to-reach forest areas. Applicable to both small-scale and large-scale forest management.

Limitations: The accuracy of results may be influenced by the quality of the imagery and the complexity of the terrain. May necessitate post-processing software and technical proficiency.

Acoustic and sonic techniques, including the measurement of sound wave velocity through a tree trunk and tree-ring analysis, can yield indirect estimates of tree volume and biomass.

Biomass Estimation: The speed of sound waves traveling through a tree trunk is affected by its density and moisture levels. By timing the travel of sound waves between two points on a tree, researchers can deduce the tree's density and estimate its biomass.

Volume Estimation: Sonic methods can also evaluate the internal structure of the tree, allowing for volume estimation by analysing the propagation of sound through the trunk and branches. This approach can be beneficial in assessing the health and integrity of the tree, which may influence volume estimates.

Advantages: Non-invasive and rapid. Applicable in various environmental conditions.

Limitations: Accuracy may fluctuate based on tree species and environmental factors (e.g., moisture levels). May not be appropriate for trees with intricate internal structures or decay.

Remote Sensing and Satellite Imagery Remote sensing technologies, such as satellites and aerial imaging, provide a non-invasive approach to estimating biomass and volume across extensive geographic regions. By utilizing multispectral or hyperspectral imagery, researchers can evaluate forest canopy structure, tree height, and various other forest characteristics (Roy *et al*., 2017).

Biomass Estimation: Remote sensing facilitates the gathering of data regarding forest canopy density and structure, which can be statistically correlated with biomass. Vegetation indices, including the Normalized Difference Vegetation Index (NDVI), serve as indicators of forest health and biomass levels.

Volume Estimation: In a manner similar to biomass estimation, tree volume can be derived from remote sensing data through algorithms that consider canopy height, tree density, and spatial distribution. LIDAR and radar (SAR) data from satellites can also provide high-resolution information for volume estimation.

Advantages: Ideal for large-scale forest inventories and ongoing monitoring. Delivers frequent and updated data, particularly with the advent of recent satellite missions.

Limitations: Necessitates advanced software and data processing capabilities. May exhibit reduced accuracy in dense or heterogeneous forest settings.

CONCLUSION

Non-destructive techniques for estimating tree biomass and volume offer significant benefits for forest management, ecological research, and environmental monitoring. These methods reduce the ecological footprint associated with tree measurement and are often more cost-effective and efficient compared to traditional approaches that involve tree removal. As technological advancements continue, the incorporation of tools such as LiDAR, UAVs, photogrammetry, and remote sensing is anticipated to enhance the precision and scalability of biomass and volume estimations, thereby fostering more sustainable forest management practices.

REFERENCES

Montes, N., Gauquelin, T., Badri, W., Bertaudiere, V., & Zaoui, E. H. (2000). A non-destructive

method for estimating above-ground forest biomass in threatened woodlands. Forest Ecology and Management, 130(1-3), 37-46.

Roy, P. S., Behera, M. D., & Srivastav, S. K. (2017). Satellite remote sensing: sensors,

applications and techniques. Proceedings of the National Academy of Sciences, India Section A: Physical Sciences, 87, 465-472.