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Editorial

Advances in Forest Resources Inventory, Monitoring, and Assessment

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Forest resources inventory, monitoring, and assessment provide scientific support for sustainable forest management, carbon accounting, and decision-making. The field is undergoing rapid methodological transformation as global interest in forest carbon sequestration intensifies alongside the traditional demand for timber supply and ecosystem services. Conventional field inventories, while reliable, are being augmented—and, in some cases, redefined—by Internet of Things (IoT) sensors, unmanned aerial vehicles (UAVs), airborne LiDAR, and advanced statistical and machine-learning models. This Special Issue of *Forests* presents nine papers that collectively illustrate the breadth of current innovation and the persistent challenges regarding accuracy, compatibility, and comparability across scales.

The first cluster of contributions advances ground-based measurement technology, addressing a long-standing bottleneck in forest inventories: the trade-off between data richness and operational efficiency. Cao et al. [1] designed and field-tested an IoT-based Smart Tree Monitoring Network for continuous standing-tree DBH observation. Deployed across 426 devices in 10 sample plots spanning different terrain and climatic conditions in Hubei Province, China, the system demonstrated strong agreement with manual measurements (R^2 = 0.9996; RMSE = 0.215 cm) and a theoretical battery life of nearly a decade under tested duty-cycle assumptions. The authors candidly note, however, that long-term measurement drift, end-to-end data completeness, battery aging under field conditions, and physical durability require further validation—a reminder that technological promise must always be tempered by rigorous field evidence. Xu et al. [2] developed an integrated forestry survey device combining laser ranging and tunnel magnetoresistance to measure tree height and DBH simultaneously, achieving 98% DBH accuracy at low cost and in a compact form factor. Yet the height RMSE of 31–55 cm still falls short of the precision (<20 cm) required for high-precision forest resource surveys, indicating a clear direction for future improvement. Together, these studies signal a shift toward automated, high-frequency data collection as a complement to—rather than a replacement for—periodic inventory campaigns, and they underscore that the path from prototype to operational tool is paved with unresolved questions about calibration, durability, and scale.

The second cluster addresses biomass and growing-stock estimation, wherein regional specificity and model compatibility remain critical determinants of accuracy. Du et al. [3] constructed compatible biomass models for Chinese fir, poplar, and oak in Hunan Province, China, based on 461 felled-tree specimens sampled from 14 administrative cities from 2022 to 2023. Their hierarchical compatible model structures—established through algebraic component summation and proportional scaling under simultaneous equation constraints—achieved a prediction accuracy above 96% for total and aboveground biomass while guaranteeing strict compatibility between total and component predictions. This

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property is essential for carbon accounting, where inconsistencies between component and total estimates can propagate into systematic errors. Garcia et al. [4] compared 30 tree-level biomass models in the Amazon using 200 simulated 1 ha plots representing advanced secondary forests and mature forests. Their findings are sobering: 15 and 4 models under- and overestimated, respectively, plot-level biomass beyond the acceptable accuracy (overall ±10%), and the strongest—though still moderate—correlation with plot-level error was the RMSE of the models themselves. The authors caution that selecting a model among several based on the lowest RMSE is misleading because tree-level precision does not guarantee plot-level accuracy, a methodological warning with implications far beyond the Amazon. Yang et al. [5] estimated growing-stock volume for Chinese fir plantations in Southern China using UAV laser scanning across 138 plots. Their nonlinear mixed-effects models outperform base and linear alternatives at both tree and stand levels (stand-level R^2 = 0.785–0.879), and they demonstrate that area-level random effects primarily influence baseline values, while plot-level random effects shape allometric relationships, underscoring the necessity of incorporating spatial heterogeneity into volume estimation.

The third cluster examines inventory methodology and large-scale monitoring, revealing how methodological choices shape what we can reliably infer from forest data. Georgakis and Diamantopoulou [6] uncovered a 19% underestimation in compartment-level growing-stock volume at the University Forest of Pertouli in Greece during a transition from full-callipering to a systematic-sample-plot inventory. Their four-hypothesis diagnostic framework, combining linear mixed models with non-parametric bootstrap resampling, attributes approximately 96% of the implied decadal change to baseline-year underestimation, a deviation invisible without their framework and one that would otherwise distort prescribed cut calculations. This study provides a transferable retrospective consistency assessment for inventory time series crossing methodological discontinuities, a situation increasingly common as national forest inventories modernize. Potter et al. [7] used approximately 40,000 Nationwide Forest Inventory plots to show that U.S. National Forests are more diverse, denser, and less invaded by non-native plants than neighboring forests within 25 km. Controlling for environment, geography, and forest composition, they found significantly greater tree species and structural diversity, basal area, biomass per hectare, and seedling density on National Forest System land, illustrating the value of systematic broad-scale monitoring for policy and management and demonstrating how inventory data can be repurposed to answer questions about the effectiveness of different ownership and management regimes.

Finally, two contributions extend forest assessment into spatial prediction and habitat modeling, pushing the field from description to anticipation. Zhou et al. [8] integrated voxel-based 3D canopy metrics from airborne LiDAR into Random Forest models for aboveground biomass estimation across five forest types. Their enhanced models, incorporating voxel canopy height, canopy volume, and canopy surface area alongside traditional height and density metrics, improve accuracy by 2.1% to 32.7% relative to the traditional models (R^2 in 0.480–0.607), with the largest gains obtained for structurally complex broadleaf forests, precisely where traditional approaches struggle most. The wall-to-wall AGB map they generated (total stock: 8.36×10^6 t) demonstrates the operational potential of voxel-based metrics for stand-scale monitoring. Nie et al. [9] applied an optimized MaxEnt model to predict suitable habitats for six timber tree species in Sichuan Province, China, under current and future (2061–2080) climate scenarios (SSP126 and SSP585). Their projections reveal significant range shifts of 5–101 km southwestward, with species-specific responses: the high-suitability area for *Phoebe zhennan* is projected to increase from 12,788 km^2 to 20,004 km^2 under SSP585, while that for *Eucalyptus robusta* is expected to contract from 8706 km^2 to 7715 km^2. Altitude emerged as the dominant environmental factor, and the

statistically significant ($p < 0.01$) migration trends provide actionable scientific support for forestry planning, forest quality improvement, and climate risk mitigation.

Collectively, these nine papers demonstrate that forest resource inventory, monitoring, and assessment is evolving along three axes: from discrete to continuous observation, from single- to multi-scale integration, and from descriptive to predictive analytics. The IoT sensor networks and integrated survey devices in the first cluster point to a future of high-frequency, networked data streams; the biomass and volume studies in the second cluster reveal both the power and peril of model-based inference when regional calibration and cross-scale compatibility are neglected; the methodological and monitoring contributions in the third cluster show that the reliability of our estimates depends as much on how we sample and compare as on what we measure; and the spatial prediction studies in the fourth cluster extend the temporal and spatial horizons of assessment to anticipatory management. Yet, across all four clusters, enduring tensions persist between local calibration and national consistency, tree- and plot-level accuracy, technological promise and field validation, and methodological innovation and operational reliability. Addressing these tensions will require sustained investment in methodological rigor, data interoperability, and long-term monitoring infrastructure. It will also require a culture of honest reporting regarding limitations, as exemplified by the authors in this Special Issue who candidly acknowledge where their systems fall short. I hope this Special Issue stimulates further research and practical innovation in this essential field and serves as a useful reference for those working to build the next generation of forest inventory, monitoring, and assessment systems.

Conflicts of Interest: The author declares no conflicts of interest.

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