

基于主动遥感数据的林木测树因子及用表研建

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摘要:【目的】本研究利用高精度激光扫描获取无损、高效的单木点云数据, 建立一种新的立木测树因子方法, 更新了研究区银杏立木材积, 提高林业调查效率和准确率, 减少资源浪费, 推动林业管理现代化和可持续发展。【方法】首先, 获取了研究区全林分地面激光(TLS)数据和无人机载激光(ULS)数据, 并通过实地踏查得到银杏人工林胸径数据, 共 1192 株; 分别对地面和机载两套数据完成单木分割, 测定机载数据中的树高、冠幅, 利用最小二乘法得到 TLS 数据中的上部直径, 计算出单株材积。然后, 直接编制一元材积表并进行评价检验。按冠幅大小将立木分成大、中、小三个冠幅, 构建银杏立木削度方程, 用最优模型编制出材率表并进行模型评价和指标验证; 接着, 利用 ULS 数据处理获取单木点云特征参数, 分三个冠幅级别拟合材积-树高模型, 利用随机森林的递归特征消除法分析所有特征参数和材积值的相关性, 选取相关性高的特征参数进入随机森林模型, 反演一元材积-树高模型, 编制出树高级一元材积表, 并进行检验。【结果】(1) 利用 TLS 数据编制的最佳一元材积式为 $V=0.0002D^2+0.0084D-0.089$, $R^2=0.744$ 。削度模型为 $d^2=0.670D^{1.595}(H-h)^{2.659}/H^{2.58}$, $R^2=0.867$, 两式检验后得到无系统偏差结论, 编制得到一元材积表和出材率表。(2) 将一元材积-树高模型和随机森林模型分别对其预估值与实测材积值进行一元线性回归分析对比, 结果是随机森林材积模型精度更高。(3) 选择与材积相关性最高的单木点云特征参数: elev_mean 和 density_metrics[3]加入随机森林材积模型中, 解的训练集数据模型 $RMSE=0.162$, $R^2=0.807$, $RRMSE=0.623$, $MAE=0.067$; 测试集数据模型 $RMSE=0.142$, $R^2=0.837$, $RRMSE=0.662$, $MAE=0.072$ 。(4) 根据随机森林模型分冠幅级别研建树高级一元材积表。【结论】激光扫描的主动遥感技术为测树研究提供了高效、无损的活立木数据, 经过对研究区银杏一元材积表和出材率表的编制, 发现单株冠幅与胸径成正比, 综合不同冠幅造材结果来看, 冠幅越大, 银杏材种的总出材率越大, 即造材利用率相对更高。同时, 本研究基于机载数据建立的树高级材积表, 为研究区经营弥补了基础数表, 也为今后基于无人机激光数据建立林业数表提供了有效方法。

关键词: 一元材积表; 削度方程; 出材率; 随机森林模型; 树高级一元材积表

Tree measurement factors based on active remote sensing data and the construction of the corresponding tables

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Abstract: 【Objective】 This research employs high-precision laser scanning to acquire non-destructive and efficient single-tree point cloud data, establishes a novel method for measurement tree factors of standing trees, updates the volume of Ginkgo biloba standing trees in the study area, enhances the efficiency and accuracy of forestry surveys, reduces resource waste, and promotes the modernization and sustainable development of forestry management. 【Methods】 Firstly, the terrestrial laser scanner (TLS) data and UAV-borne laser scanner (ULS) data of the whole stand in the study area were obtained, and the DBH data of Ginkgo biloba plantation were obtained through field investigation, a total of 1192 trees. The tree height and crown width in airborne data were determined.

The upper diameter in TLS data was obtained by least square method, and the volume of individual tree was calculated. Then, the one-way volume table is directly compiled and evaluated. The trees were divided into large, medium and small crown lengths according to crown width, and the cutting degree equation of ginkgo biloba was constructed. The wood yield table was compiled with the optimal model, and the model evaluation and index verification were carried out. Then, ULS data processing was used to obtain the characteristic parameters of single tree point cloud, and the volume-tree height model was fitted into three crown levels. The recursive feature elimination method of random forest was used to analyze the correlation between all feature parameters and volume values. The feature parameters with high correlation were selected to enter the random forest model, and the unitary volume-tree height model was inverted to compile the comprehensive single-entry volume table of the tree. And test. **【Results】** (1) The optimal one-dimensional volume formula derived from TLS data is $V = 0.0002D^2 + 0.0084D - 0.089$, with $R^2 = 0.744$. The slope model is $d^2 = 0.670D^{1.595}(H-h)^{2.659}/H^{2.58}$, with $R^2 = 0.867$. After testing the two models, it was concluded that there is no systematic bias, and a one-dimensional volume table and outage rate table were compiled. (2) The one-dimensional volume-tree height model and random forest model were respectively used for one-dimensional linear regression analysis of their predicted volume values and actual volume values, and the results showed that the random forest volume model had higher accuracy. (3) The elev_mean and density_metrics[3] feature parameters of the single tree point cloud with the highest correlation with volume were selected and added to the random forest volume model, and the training set data model RMSE=0.162, $R^2=0.807$, RRMSE=0.623, MAE=0.067; the test set data model RMSE=0.142, $R^2=0.837$, RRMSE=0.662, MAE=0.072. (4) A comprehensive single-entry volume table was established based on the random forest model by dividing the crown width level.

【Conclusion】 The active remote sensing technology of laser scanning provides efficient and non-destructive live tree data for tree measurement research. After compiling the one-way volume table and percentage of outturn table for Ginkgo biloba, it was found that the single crown area is proportional to the trunk diameter. Combining the different crown construction results, the larger the crown area, the higher the total percentage of outturn of Ginkgo wood species, i.e. the higher the relative utilization rate of wood. At the same time, the comprehensive single-entry volume table established based on the onboard data fills the basic data table for the study area, and provides an effective method for establishing forestry data tables based on drone laser data in the future.

Keywords: one-way volume table; taper equation; percentage of outturn; random forest model; comprehensive single-entry volume table