

Article

Individual Tree AGB Estimation of *Malania oleifera* Based on UAV-RGB Imagery and Mask R-CNN

Maojia Gong ¹, Weili Kou ^{2,*}, Ning Lu ² , Yue Chen ³ , Yongke Sun ², Hongyan Lai ¹, Bangqian Chen ⁴ , Juan Wang ⁵ and Chao Li ⁶

- ¹ College of Forestry, Southwest Forestry University, Kunming 650224, China; gongmaojia@163.com (M.G.); lhy19931006@163.com (H.L.)
 - ² College of Big Data and Intelligent Engineering, Southwest Forestry University, Kunming 650224, China; ninglu@swfu.edu.cn (N.L.); sunyongke@swfu.edu.cn (Y.S.)
 - ³ College of Mechanics and Transportation, Southwest Forestry University, Kunming 650224, China; chenryue960504@163.com
 - ⁴ Rubber Research Institute (RRI), Chinese Academy of Tropical Agricultural Sciences (CATAS), Hainan Danzhou Agro-Ecosystem National Observation and Research Station, Haikou 571101, China; chbq40@163.com
 - ⁵ Eco-Development Academy, Southwest Forestry University, Kunming 650224, China; schima@163.com
 - ⁶ Cigarette Product Quality Test Center, Technology Center of China Tobacco Yunnan Industrial Co., Ltd., Kunming 650023, China; super88man66@126.com
- * Correspondence: kwl@swfu.edu.cn

Abstract: Forest aboveground biomass (AGB) is an important research topic in the field of forestry, with implications for carbon cycles and carbon sinks. *Malania oleifera* Chun et S. K. Lee (*M. oleifera*) is a valuable plant species that is listed on the National Second-Class Protected Plant checklist and has received global attention for its conservation and resource utilization. To obtain accurate AGB of individual *M. oleifera* trees in a fast, low-finance-cost and low-labor-cost way, this study first attempted to estimate individual *M. oleifera* tree AGB by combining the centimeter-level resolution RGB imagery derived from unmanned aerial vehicles (UAVs) and the deep learning model of Mask R-CNN. Firstly, canopy area (CA) was obtained from the 3.5 cm high-resolution UAV-RGB imagery using the Mask R-CNN; secondly, to establish an allometric growth model between the diameter at breast height (DBH) and CA, the correlation analysis of both was conducted; thirdly, the AGB estimation method of individual *M. oleifera* trees was presented based on an empirical equation. The study showed that: (1) The deep learning model of Mask R-CNN achieved an average segmentation accuracy of 90% in the mixed forests to the extraction of the canopy of *M. oleifera* trees from UAV-RGB imagery. (2) The correlation between the extracted CA and field-measured DBH reached an R^2 of 0.755 ($n = 96$). (3) The t -test method was used to verify the predicted and observed values of the CA-DBH model presented in this study, and the difference in deviation was not significant ($p > 0.05$). (4) AGB of individual *M. oleifera* was estimated for the first time. This study provides a reference method for the estimation of individual tree AGB of *M. oleifera* based on centimeter-level resolution UAV-RGB images and the Mask R-CNN deep learning.

Keywords: *Malania oleifera*; aboveground biomass; UAV; Mask R-CNN; allometric growth model



Citation: Gong, M.; Kou, W.; Lu, N.; Chen, Y.; Sun, Y.; Lai, H.; Chen, B.; Wang, J.; Li, C. Individual Tree AGB Estimation of *Malania oleifera* Based on UAV-RGB Imagery and Mask R-CNN. *Forests* **2023**, *14*, 1493. <https://doi.org/10.3390/f14071493>

Academic Editor: Rafael María Navarro-Cerrillo

Received: 8 June 2023

Revised: 17 July 2023

Accepted: 17 July 2023

Published: 21 July 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Malania oleifera Chun & S. K. Lee (*M. oleifera*) is a rare, high-value, and protected species of evergreen broad-leaved trees found in arid regions. It belongs to the genus *Malania* within the Olacaceae family and is highly valued for its fruits, leaves, and trunk [1]. The kernels of *M. oleifera* contain over 60% oil and can be used to extract edible and aromatic oils [2]. Its fruit oil is also rich in neuronc acid, an important material for treating neurological diseases and promoting brain growth and nerve regulation [2]. *M.*

云南广西蒜头果适生区预测及环境影响因子

龚茂佳¹, 王娟², 付小勇³, 寇卫利^{3*}, 鲁宁³, 王秋华⁴, 赖虹燕¹

(1. 西南林业大学林学院, 云南 昆明 650224; 2. 西南林业大学绿色发展研究院, 云南 昆明 650224;

3. 西南林业大学大数据与智能工程学院, 云南 昆明 650224; 4. 西南林业大学

土木工程学院, 云南 昆明 650224)

摘要:【目的】蒜头果(*Malania oleifera*)是一种兼有很高经济和生态价值的濒危植物。本研究旨在揭示云南、广西蒜头果的潜在适生区的空间分布格局,并且明确其主要环境影响因子,为蒜头果的保护与开发利用提供理论基础。【方法】通过野外调查、数字标本植物馆、全球生物多样性信息网络等方式获取了蒜头果样本 136 个。选取常见的 20 个主要环境因子作为参数,基于最大熵模型(MaxEnt)和 ArcGIS 地理信息系统平台构建了蒜头果潜在适生区预测模型,模拟蒜头果在云南和广西壮族自治区的潜在适生区。【结果】笔者构建的 MaxEnt 模型预测得到蒜头果的潜在适生区分布范围为 104°~107°E 及 22°~26°N,预测适生区验证结果的受试者工作特征曲线下方的面积(AUC)均超过 0.9。MaxEnt 预测的蒜头果潜在适生区前 4 个环境影响因子及贡献率依次为:气温季节性变动系数因子(39.6%)、等温性因子(16.7%)、平均气温因子(13.7%)、气温年较差因子(11.5%)。【结论】云南文山州东南部以及广西西部是蒜头果的集中分布区,温度是影响蒜头果分布的主要因素,MaxEnt 模型在蒜头果适生区预测中表现出极高的精度和可靠性。该研究将为蒜头果资源保护利用和人工繁育选址提供重要依据。

关键词: 蒜头果; MaxEnt 模型; 适生区; 环境因子; 空间分布

中图分类号: Q949.741.2; Q948.13

文献标志码: A

开放科学(资源服务)标识码(OSID):

文章编号: 1000-2006(2022)02-0044-09



Suitable regions forecasting and environmental influencing factors of *Malania oleifera* in Yunnan and Guangxi

GONG Maojia¹, WANG Juan², FU Xiaoyong³, KOU Weili^{3*}, LU Ning³, WANG Qiuhua⁴, LAI Hongyan¹

(1. College of Forestry, Southwest Forestry University, Kunming 650224, China; 2. Eco-Development

Academy, Southwest Forestry University, Kunming 650224, China; 3. College of Big Data

and Intelligence Engineering, Southwest Forestry University, Kunming 650224, China;

4. College of Civil Engineering, Southwest Forestry University, Kunming 650224, China)

Abstract 【Objective】*Malania oleifera* is an endangered plant with high economic and ecological value. This study focuses on discovering the spatial distribution pattern of potential suitable areas of *M. oleifera*, and finding its main environmental affecting factors, laying a solid theory foundation for its conservation and utilization. 【Method】This study got 136 sampling points of *M. oleifera* by field investigations, specimens of the digital library, and the global biodiversity information network. Based on the ArcGIS geographic information system platform and the maximum entropy model (MaxEnt) with parameters of 20 common main environmental factors, the prediction model of *M. oleifera* potential suitable areas was built to simulate the *M. oleifera* distribution in Yunnan Province and Guangxi Zhuang Nationality Autonomous Prefecture (Guangxi). 【Result】The results showed that of *M. oleifera* is mainly distributed in the longitude of 104°-107°E and the latitude of 22°-26°N. The area under the curve (AUC) of potential suitable areas predicted by

收稿日期 Received: 2021-09-25

修回日期 Accepted: 2022-01-05

基金项目: 国家自然科学基金项目(31760181, 31400493); 云南省农业基础研究联合专项项目(2017FG001-034, 2018FG001-059); 云南省重大科技专项生物资源数字化开发应用项目(202002AA10007)。

第一作者: 龚茂佳(2429801264@qq.com)。* 通信作者: 寇卫利(kwl_eric@163.com) 教授。

引文格式: 龚茂佳, 王娟, 付小勇, 等. 云南广西蒜头果适生区预测及环境影响因子[J]. 南京林业大学学报(自然科学版), 2022, 46(2): 44-52. GONG M J, WANG J, FU X Y, et al. Suitable regions forecasting and environmental influencing factors of *Malania oleifera* in Yunnan and Guangxi[J]. Journal of Nanjing Forestry University (Natural Sciences Edition), 2022, 46(2): 44-52. DOI: 10.12302/j.issn.1000-2006.202109039.