An Estimation Method for Annual Biomass Increment of Individual Populus euphratica Stems Based on Tree-Ring Information (Postprint)

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Abstract

Populus euphratica serves as a key tree species in the desert riparian forests of the Tarim River, playing an important ecological role in soil and water conservation and desertification suppression. Populus euphratica biomass is an important indicator for studying the functions and services of desert riparian forest ecosystems. Populus euphratica is a nationally second-class protected tree species and the only arbor species rooted in the desert, making it extremely precious and difficult to measure using destructive methods on a large scale; therefore, biomass calculation for Populus euphratica has always been a challenging problem. Through a less destructive sampling method for Populus euphratica, tree ring information at different trunk heights was extracted. The experimental results show: There exists a significant correlation between tree ring growth at different heights, with an average correlation coefficient of 0.878; the trunk densities at heights of 0-0.5 m, 0.5-1 m, 1-1.5 m, 1.5-2 m, and 2-2.5 m are 500.2 $kg \cdot m^{-3}$, 475.6 $kg \cdot m^{-3}$, 502.2 $kg \cdot m^{-3}$, 477.2 $kg \cdot m^{-3}$, and 420.194 $kg \cdot m^{-3}$, respectively, with an average density of 471.4 $kg \cdot m^{-3}$ and a standard deviation of 32.7; Based on the obtained tree ring information at different trunk heights and trunk density, the annual biomass of a Populus euphratica trunk can be accurately calculated; in the experiment, for a 1-m-long trunk section at 0.5-1.5 m height of a Populus euphratica tree, the annual new biomass from 1997-2013 ranged from 0.61 to 1.54 kg, with an average annual new biomass of 0.92 kg; in 2002-2003, the biomass increase was particularly significant, with an average annual new biomass of 1.54 kg. The trunk biomass calculation method used by the authors is less destructive to trees and highly practical, capable of calculating trunk new biomass, which holds great significance for research on changes in the new biomass and ecological value of Populus euphratica.

Full Text

Preamble

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1 Introduction

Populus euphratica forests in the Tarim River basin play a crucial role in maintaining ecological stability and mitigating sandstorm damage in arid regions. Located between 39°10' 0.00" ~40°35' 12.84" N and 88°27' 29.88" ~87°33' 48.96" E, this area has a temperate continental arid climate with an average annual temperature of 10.8°C and annual precipitation of only 20–50 mm. The natural vegetation includes Tamarix chinensis, Haloxylon ammodendron, Alhagi sparsifolia, Apocynum venetum, and Karelinia caspica.

To calculate stem net biomass, we developed a minimally destructive sampling method. Experimental samples were collected from five different trunk heights (0.5 m, 1 m, 1.3 m, 1.5 m, and 2 m) across 40 individual trees. The trunk was divided into five segments (0–0.5 m, 0.5–1 m, 1–1.5 m, 1.5–2 m, and 2–2.5 m) for analysis

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1.1 Study Area and Sampling

In July 2014, we established experimental plots in the lower reaches of the Tarim River (40°23'48.1"N, 87°56'14.6"E). Five representative Populus euphratica trees were selected for stem analysis [FIGURE:2]. Tree-ring widths were measured using a LINTAB table (precision: 0.001 mm) to obtain annual growth data.

1.2 Tree-Ring Analysis

Tree-ring samples were processed using standard dendrochronological methods. Cross-dating was performed to ensure accurate dating of each annual ring. The

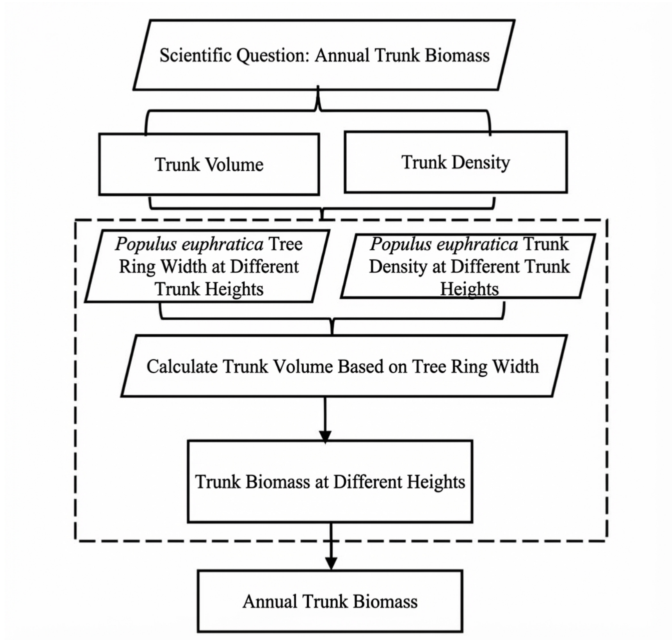

Figure 1: Figure 1

Pearson correlation coefficient was used to analyze relationships between ring widths at different heights.

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2 Methods and Results

2.1 Tree-Ring Width Correlation Analysis

Our analysis revealed significant correlations between tree-ring growth at different trunk heights, with an average Pearson correlation coefficient of 0.878. This indicates that ring-width patterns are consistent along the vertical profile of the trunk, allowing for reliable biomass estimation from limited samples.

2.2 Wood Density Measurements

Wood density was measured at five trunk height intervals: - 0–0.5 m: 500.2 $kg \cdot m^{-3}$ - 0.5–1 m: 475.6 $kg \cdot m^{-3}$ - 1–1.5 m: 502.2 $kg \cdot m^{-3}$ - 1.5–2 m: 477.2 $kg \cdot m^{-3}$ - 2–2.5 m: 420.2 $kg \cdot m^{-3}$

The standard deviation across all measurements was 32.7 $kg \cdot m^{-3}$, indicating relatively uniform density distribution.

2.3 Biomass Calculation Models

Volume Calculation:
The volume of each trunk segment was calculated using the formula for a frustum:

$$\Delta v = h \times \pi \left[r_i^2 + r_i \times R_i + R_i^2\right] - h \times \pi \left[r_{i-1}^2 + r_{i-1} \times R_{i-1} + (R_{i-1})^2\right]$$

where:
Δv = volume of segment (m^3)
h = segment height (m)
r , r 1, R , R 1 = inner and outer radii at upper and lower boundaries (m)

Biomass Calculation:
Biomass was derived from volume using wood density:

$$\Delta w = \rho \times \left(2r_i \times d_i + r_i \times D_i + 2R_i \times D_i + d_i \times D_i - d^2\right)$$

where:
Δw = biomass (kg)
= wood density ($kg \cdot m^{-3}$)
d, D = inner and outer diameters (m)

Allometric Model:
Based on diameter at breast height (D) and tree height (H), we developed the following allometric equation for stem volume:

$$V = 0.000050156 \times D^{2.08997} \times H^{0.741585}$$

where:
V = stem volume (m^3)
D = diameter at breast height (cm)
H = tree height (m)

2.4 Annual Biomass Estimates

Applying these methods, we calculated annual stem biomass for the 0.5–1.5 m trunk segment from 1997-2013. Results showed: - Annual biomass ranged from 0.61 to 1.54 kg - Average annual biomass: 0.92 kg - Notable increase during 2002–2003, with average biomass reaching 1.54 kg

These findings align with previous studies by Shao et al., Grumlich, and Rathgeber, validating our minimally destructive approach for estimating individual tree annual biomass in Populus euphratica forests.

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Figures

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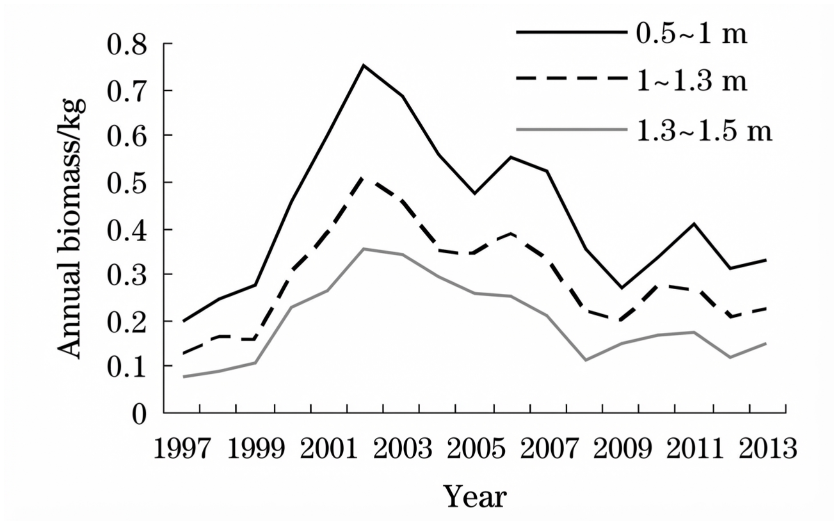

Figure 2: Figure 3

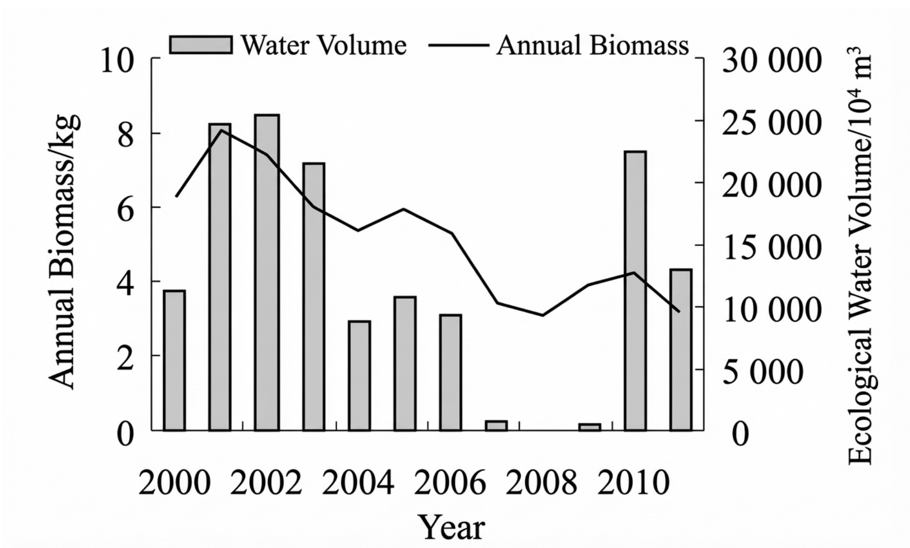

Figure 3: Figure 4