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ORIGINAL RESEARCH PAPER

Forestry Science

COMPARISON OF BIOMASS MEASUREMENTS WITH MODERN AND CLASSICAL INSTRUMENTS.

KEY WORDS: forest biomass, stacked lumber, SLAM GNSS

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ABSTRACT

Forest biomass includes organic materials from forest ecosystems, such as wood, leaves, and branches, and is an important natural resource for the production of timber, bioenergy, and other products. Sustainable management of it is crucial for the protection of forest ecosystems, reducing the risk of fires, and utilizing natural resources. The estimation of forest biomass can be done through methods based on weight or spatial volume measurements. The conversion factor allows for the calculation of the net wood volume, defining the relationship between total volume and actual timber. Forest policy plays a crucial role in the responsible management of biomass, promoting modern technologies for fire prevention and efficient resource management. The SLAM GNSS RTK 3D scanning technology offers precise and fast mapping of forest areas, creating 3D models of timber that are analyzed with software such as CoPre and CloudCompare. The study focuses on comparing three methods for measuring firewood in Agia Eleousa: traditional measurement, the Huber method, and SLAM 3D GNSS RTK. The results showed that the Huber method is the most reliable for non-stacked timber, while the SLAM technology, although offering fast mapping, overestimates the volume due to gaps between log segments.

INTRODUCTION

The management of forest biomass is crucial for the sustainable utilization of natural resources, reducing the risk of forest fires, and supporting a circular economy. The removal of excess wood from forest ecosystems helps reduce fuel loads, protecting natural areas and infrastructure from fires. The commercial use of firewood enhances the economy and energy production, making accurate volume estimation critical for the rational management of reserves.

The traditional approach to measuring firewood volume is based either on weight measurements or cubic meters. Weight measurements are performed on wood transport trucks and are heavily influenced by the moisture content of the wood, which requires sampling and conversion to dry weight. Measurement in cubic meters is based on the volume of stacked wood, which depends on the geometry of the stacking. The cubic meters of a stack are calculated using the type:

V=L×W×HV=L

where:

- V = cubic volume (m^3)
- L = pile length (m)
- W = pile width (m)
- H = pile height (m)

However, because there are gaps between the logs in stacks, a conversion factor is used to calculate the net wood volume:

$$F = \frac{V}{R}$$

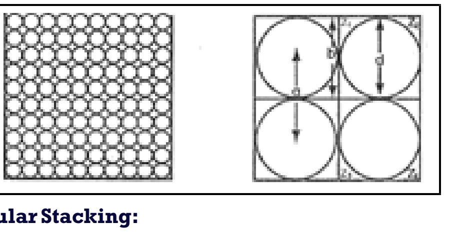
Where:

- F = conversion factor
- R = total cubic volume

The values of the conversion factors depend on the stacking method and the type of wood. For example, the conversion factors for different stacked log arrangements are:

Square Stacking:

$$F_1 = \frac{\frac{\pi}{4} \times d^2 \times l}{d^2 \times l} = \frac{\pi}{4} = 0{,}785$$



Triangular Stacking:

$$F_2 = \frac{\frac{\pi}{4} \times d^2 \times l}{\frac{\sqrt{3}}{2} \times d^2 \times l} = \frac{\pi}{2 \times \sqrt{3}} = 0{,}906$$

Combined Stacking:

$$F_3 = \frac{\frac{\pi}{4} \times d^2 \times l + \frac{\pi}{4} \times d^2 \times l}{d^2 \times l + \frac{\sqrt{3}}{2} \times d^2 \times l} = \frac{\frac{\pi}{2}}{1 + \frac{\sqrt{3}}{2}} = \frac{\pi}{2 + \sqrt{3}} = 0{,}842$$

Additionally, the values of the conversion factor vary depending on the species of wood, as shown in the following table:

Table – 1 Values Of The Conversion Factor For Certain Greek Forestry Species And Categories Of Stacked Wood

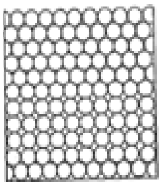
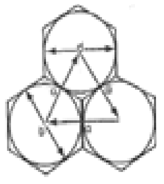
SPECIES	CONVERSION FACTOR
Chestnut round fuelwood	0.637
Oak round fuelwood	0.566
Oak split fuelwood	0.618
Oak round wood for technical uses	0.696
Oak split wood for technical uses	0.701
Oak piles	0.656
Black pine round fuelwood	0.628
Black pine round poles	0.748
Black pine wood for technical uses with bark	0.714
Black pine wood for technical uses without bark	0.770

Fir round fuelwood	0.643
Fir split fuelwood	0.680
Fir industrial roundwood	0.724
Fir round wood for technical uses	0.759

However, in cases where no predefined conversion factor exists, a more accurate estimation method is required, such as Huber's formula, which is used to calculate the net volume of logs:

$$V = \frac{\pi}{4} \cdot d_m^2 \cdot L$$

Where:
- dm = diameter at the midpoint of the log (m)
- L = length of the log (m)

This method is applied through sampling measurements of logs, providing greater accuracy in cases of non-stacked wood. With technological advancements, 3D SLAM GNSS RTK scanning has been introduced as an alternative method for measuring wood volume. Using LiDAR and GNSS RTK data, this technology creates 3D models of wood piles, offering rapid mapping. However, its accuracy remains under investigation, as it records the gaps between the logs, leading to an overestimation of the total volume.

This study compares three methods for measuring firewood volume in the area of Agia Eleousa, where logging was carried out without applying ideal stacking practices. Initially, the traditional method of measuring stacked wood, which relies on the geometric mapping of the piles and the application of fixed conversion factors, was tested. However, irregular stacking made it impossible to apply this method, highlighting the need for alternative measurement methods.

Figure 1: Location of biomass concentration.

For This Reason, Two Approaches Were Applied:
- Huber's Method, where volume is calculated through log sampling and extrapolation to the total pile.
- 3D SLAM GNSS RTK Scanning, a modern technique that uses LiDAR and GNSS data to map the total geometry of the wood.

Huber's method proved reliable as it does not require uniform stacking to estimate the net wood volume. On the other hand, the 3D SLAM GNSS RTK technique, while providing quick mapping, overestimated the total volume due to recording the gaps between the logs. The study evaluates the accuracy, reliability, and suitability of each method to determine the most appropriate technique when the stacking does not follow best practices.

The main research question addressed is which method provides the most reliable estimation of net volume when stacking does not follow optimal practices.

The Analysis Is Based On:
- Measurement accuracy relative to the actual volume of the wood.
- The impact of irregular stacking on the results of each method.
- Time and ease of application of different techniques.

The findings of the study will contribute to the development of guidelines for selecting the most suitable firewood measurement method, providing valuable information for forest management and the commercial assessment of timber.

Case Study

In Agia Eleousa, volume measurements were carried out using three different methods: the traditional method for stacked wood, Huber's method, and 3D SLAM GNSS RTK scanning. The irregular stacking of the wood made the application of the traditional method impossible, as it relies on geometric mapping of the piles and the use of fixed conversion factors. For this reason, alternative techniques were applied:
- Huber's Method, where sampling measurements of logs were conducted, the total number of logs was counted, and the total volume was extrapolated. The results were expressed in cubic meters (m^3) and converted to stacked cubic meters (ch.m^3).
- 3D SLAM GNSS RTK Scanning, where a CHCNAV RS10 scanner was used to calculate the volume of the piles using the ellipsoid formula.

For log measurements, tape measures, calipers, and stadia were used to ensure accuracy in the measurements.

Application Of The Huber Method For Wood Pile Volume Estimation In Agia Eleousa

In the Agia Eleousa area, the traditional measurement method could not be applied due to the irregular stacking of the wood, as the lack of uniform arrangement made the volume estimation inaccurate when using fixed conversion factors. For this reason, the Huber method was applied, which is based on a sampling approach to estimate the net volume of the log pieces.

For Data Collection, Measurements Of Log Dimensions Were Taken Using The Following Instruments:
- Measuring tape, for recording the length of each log piece with millimeter precision.
- Caliper, for measuring the diameter at the midpoint of the log piece.
- Stadiometer, for recording the height when necessary.

Measurements were taken on 12 representative log pieces to provide a representative estimate of the average size of the logs in the pile. From the sampling results, the average dimensions of the logs were calculated as follows:
- Average log length: 2.65 m
- Average diameter at the midpoint: 0.27875 m

After the average sizes of the log pieces were determined, the Huber formula was applied to calculate the volume of one log piece:

$$V = \frac{\pi}{4} \cdot d_m^2 \cdot L$$

Where:
- V = volume of the log piece (m^3),
- dm = diameter at the midpoint of the log (m),
- L = length of the log piece (m).

Substituting The Average Values Into The Type:

V = (3,141592/4) * 0,27875 2 * 2,65 = 0,161721

Since it was not feasible to measure all the logs individually, the total number of logs in the pile was counted. The total number of logs estimated was 200. Therefore, the average volume of a log was multiplied by the total number of logs to estimate the total volume:
Vtotal = 200 * 0,161721 = 32,34413217 m^3

Conversion to Stacked Cubic Meters (s.c.m.)
For wood handling, measurements are usually expressed in stacked cubic meters (s.c.m.), which include the gaps between the logs in the pile. The conversion is done using a conversion factor from cubic meters (m^3) to stacked cubic meters (s.c.m.).

According to the Austrian standard ÖNORM M7132, for stacked logs of 1 meter in length, the conversion factor is 0.7. Thus, the conversion was carried out as follows:
32,34413217 κ.μ. / 0,7 c.m.(1 s.c.m. stacked logs, 1m) = 46,20590311 s.c.m. = 46,20 s.c.m

Wood Measurement Using SLAM 3D Scanner/GNSS RTK in Agia Eleousa
In the Agia Eleousa area, a 3D scan of the wood piles was performed using the SLAM 3D SCANNER/GNSS RTK, which employed LiDAR technology and GNSS RTK data to create a point cloud from which the volume of the piles could be estimated.

Figure 2: Slam 3D Scanner/GNSS RTK

Data processing was carried out using the CoPre and CloudCompare software, allowing the use of external control points and the application of noise removal filters. The nominal accuracy of the device is 5 cm, and after processing the point cloud, the total accuracy was determined to be 0.081 m.

During the scanning, it was found that the wood piles exhibited significant variations in their dimensions, as they were not stacked uniformly. Therefore, multiple measurements were taken from the pile using the measure line tool in the CoPre program to calculate the average dimensions.

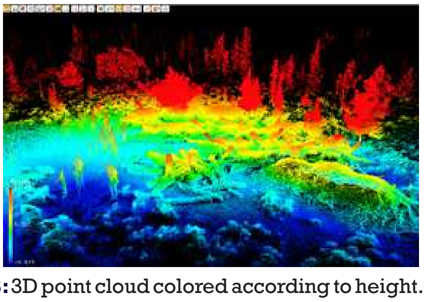


Figure 3: 3D point cloud colored according to height.

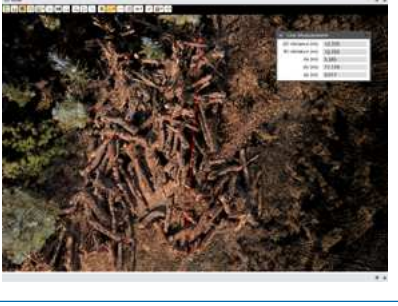


Figure 4: Measurement of length, width and height of carcasses in the area.

The Recorded Dimensions From The SLAM Measurement Were:
- **Average Pile Length:** 11.51875 m
- **Average Pile Width:** 7.50625 m
- **Average Pile Height:** 2.21875 m

Thus, the maximum radius length is 5.759375, and the minimum radius length is 3.753125.

To calculate the volume of the pile, it was assumed that the pile had a semi-ellipsoidal shape. The formula for the volume of an ellipsoid was applied:

$$V = (\frac{4}{3} \cdot \pi \cdot a \cdot b \cdot c)/2$$

Where:
V = the volume of the pile in stacked cubic meters (s.c.m.),
a = length of the maximum radius (5.759375 m),
b = length of the minimum radius (3.753125 m),
c = height of the pile (2.21875 m),
$\pi = 3.141592$.

After dividing by 2, as required to obtain the half of the geometric shape

To calculate the volume, substitute the values into the type: V= (4/3 * 3,141592 * 5,759375 * 3,753125 * 2,21875) / 2 = 100,4466298 s.c.m

CONCLUSIONS
The management of forest biomass is a crucial factor for sustainable development and fire risk reduction. Proper management policies ensure that biomass exploitation is carried out in a sustainable manner while also contributing to the protection of forest ecosystems. The uncontrolled accumulation of combustible materials increases the risk of devastating forest fires, with significant ecological and economic impacts. To address this issue, the controlled removal of biomass and the use of modern technologies are necessary.

- In the Agia Eleousa area, the wood was not stacked in the recommended way, making the traditional method of measuring stacked wood inapplicable.
- The Huber method provided an accurate estimation of the net wood volume, offering reliable results even in conditions of non-uniform stacking.
- The use of the SLAM 3D GNSS RTK allowed for quick 3D scanning of the wood piles, but due to the recording of the gaps between the logs, it significantly overestimated the total volume.
- The use of scanning technologies, such as the SLAM 3D SCANNER, can improve the recording of forest data, but adjustments to the results are necessary for accurate estimation of marketable timber.

Recommendations For Improving Biomass Management
To improve forest resource management, the following recommendations are made:
1. **Establishment Of Biomass Collection Specifications:** Proper placement of biomass collection points should take into account forest protection, ease of access, and facilitation of exploitation procedures.
2. **Improvement Of Timber Valuation Procedures:** The stacking of timber should follow standardized procedures to facilitate accurate measurement of its volume and quality. Additionally, the use of mapping technologies (LiDAR, SLAM) should be accompanied by calibration processes to avoid overestimation.
3. **Development Of Certification And Monitoring Policies:** The integration of independent auditing

mechanisms in biomass management can ensure the effective implementation of regulations and the proper removal of excess biomass from forest ecosystems.

The use of advanced technologies, combined with appropriate forestry policies, can contribute to the sustainable management of forest resources, reducing the risk of forest fires while ensuring optimal use of forest biomass.

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