
# Minimum invasive sampling method using hollow punch for tropical wood identification on Indonesian cultural heritage

**Fanany Wuri Prastiwi, Widyanto Dwi Nugroho**

**Abstract:** The collection of wood samples is an important step, especially for the identification of wood in cultural heritage. Furthermore, in wood sampling, it is preferable to avoid any damage to minimize destruction to the objects. This study aimed to observe the effectiveness of the minimally invasive sampling method using a hollow punch for wood identification on wooden cultural heritage, such as the Panji mask (Java).

The materials used as a testing model were three tropical wood species. Sampling was conducted with various diameters of hollow punch at transverse, tangential, and radial sections. The anatomical structures were compared to the features according to the IAWA list of microscopic features for hardwood identification. The result showed that the most effective method was to take samples using a 1.5 mm diameter of hollow punch at the tangential section of wood.

**Keywords**: Hollow punch, minimum invasive, tropical wood species, wood cultural heritage, wood identification

## Método de muestreo mínimamente invasivo utilizando punzones huecos para la identificación de maderas tropicales del patrimonio cultural indonesio

**Resumen:** La recogida de muestras de madera es un paso importante, especialmente para la identificación de madera en el patrimonio cultural. Además, en el muestreo de madera, es preferible evitar cualquier daño para minimizar la destrucción de los objetos. Este estudio tuvo como objetivo observar la efectividad del método de muestreo mínimamente invasivo utilizando un punzón hueco para la identificación de la madera en patrimonio cultural de madera, como la máscara Panji (Java).

Los materiales utilizados como modelo de prueba fueron tres especies de maderas tropicales. El muestreo se realizó con punzones huecos de varios diámetros en secciones transversales, tangenciales y radiales. Las estructuras anatómicas se compararon con las características según la Lista de características microscópicas para la identificación de madera dura de la IAWA. El resultado mostró que el método más eficaz era tomar muestras utilizando un punzón hueco de 1,5 mm de diámetro en la sección tangencial de la madera.

**Palabras clave:** Hollow punch, mínimamente invasivo, especies de madera tropicales, patrimonio cultural de madera, identificación de madera

## Método de amostragem minimamente invasivo utilizando punções ocos para a identificação de madeiras tropicais do património cultural da Indonésia

**Resumo:** A recolha de amostras de madeira é um passo importante e é preferível não destruir o objeto para minimizar os danos, especialmente para a identificação de madeiras do património cultural. Este estudo teve como objetivo observar a eficácia de um método de amostragem minimamente invasivo utilizando um punção oco para a identificação de algumas madeiras utilizadas em obras do nosso património cultural.

Os materiais utilizados como modelo de teste foram três espécies de madeiras tropicais. A amostragem foi efetuada com vários diâmetros de punções ocos em secções transversais, tangenciais e radiais. As estruturas anatómicas foram comparadas com as características conforme a Lista de Verificação das Características Microscópicas de Identificação de Madeiras de Folhosas da IAWA. O resultado mostrou que o método mais eficaz foi a recolha de amostras utilizando um punção oco com um diâmetro de 1,5 mm na secção tangencial da madeira.

**Palavras-chave:** Punção oco, minimamente invasivo, espécies de madeira tropical, património cultural de madeira, identificação de madeira

## Introduction

In the history of human culture or civilization, wood has been used over a long time for various purposes (Funada *et al.* 2016), such as the creation of cultural heritage objects, which play an important role in representing the culture or tradition of a region (Saha *et al.* 2019). In cultural heritage, knowledge of wood species leads to more specific information, such as the development of civilization, societal history, and the technology of wood used (Giachi *et al.* 2016; Mizuno et al. 2010; Ruffinatto et al. 2010). Information of wood species is obtained through several activities, such as wood identification.

Wood identification is an activity to determine the wood species or genus based primarily on its anatomical features, which is the cellular structure of wood. Sometimes, some physical properties such as color and odor are also useful (Hoadley 1990). The application of wood identification procedures to cultural heritage objects is limited due to several things, such as the uniqueness of the object, its aesthetics, and its function (Fioravanti *et al.* 2016). In addition, the cultural heritage object sometimes has abnormal conditions since certain parts are fragile. For example, historical wooden masks are shaped in such a way that their identification can't be done normally, namely by taking 1-2 cm3 cube samples (Jansen *et al.* 1998), which usually damages the object. Therefore, a new sampling strategy is needed to collect samples with minimum damage to the objects, such as taking piece at the back of the mask, e.g., the nose or chin, which has a thicker part.

Moreover, wood identification in cultural heritage can be done either in macroscopic or microscopic way (Wheeler and Baas 1998). Macroscopic identification is an activity to observe the wood characteristics, such as structure and properties, directly or with a loupe (10 – 12 magnification). Macroscopic identification allows a limited observation due to the historical condition of the objects, such as coating that interferes in the observation of anatomical features (Fioravanti *et al.* 2016). Meanwhile, microscopic identification is an activity to observe the wood characteristics with a microscope. Microscopic identification can be done in several ways. The identification of wood used to make a riley cabinet by Heady *et al.* (2010) was observed by SEM (Scanning Electron Microscopy) to identify the anatomical features. Another identification of objects used in cultural heritage objects was conducted using X-ray computed tomography (Stelzner and Million 2015), which is a non-destructive method in wood identification. The methods applied to wooden cultural heritage objects certainly have their advantages and disadvantages. For instance, wood identification activity with the latest technology produces more anatomical features when observed, but this method requires a high cost, while macroscopic identification is very beneficial because it doesn't damage the object, but the anatomical features obtained are limited by the physical condition of the objects, such as color, fragile parts, and thick coating (Cufar *et al.* 2019). Furthermore, the development of a minimally invasive method strongly supports wood identification activities that are in line with the efforts to conserve the wooden cultural heritage. In this study, a hollow punch was used to collect samples, which are usually used to make holes in crafts materials, including paper, plastics, textile, wood, and leather (Rines 2020). The hollow punch was used because of its simple working principle and being readily available in the market. This study used the hollow punch with the diameter of 0.8 mm, 1.0 mm, and 1.5 mm, because they are sizes that commonly found in the market and are sufficient to allow sampling with minimum damage

## Materials & Methods

The wood species used are those that are commonly used in Yogyakarta (Java), Indonesia as a raw material for wooden mask crafts, namely jaranan (*Lannea coromandelica*), pulai (*Alstonia* spp.), and sengon (*Falcataria moluccana*) (Prayekti *et al.* 2009). In this study, three wooden blocks of jaranan, pulai, and sengon [Figure 1A] were used as a testing method, while the Panji mask replica (made in August 2020) was used to verify the chosen method [Figure 1B]. Hollow punch [Figure 1C], also known as

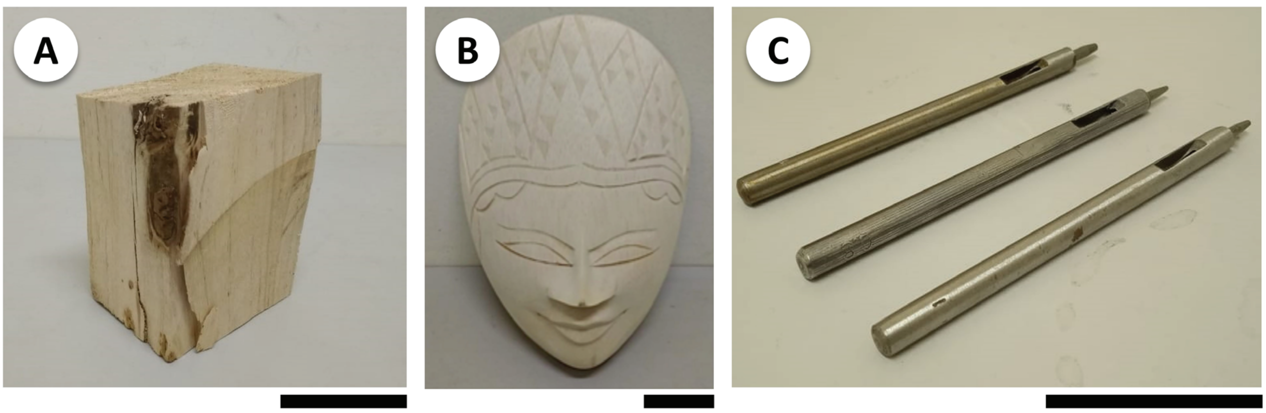


**Figure 1**.- (A) Wood block samples for testing method; (B) Panji mask replica to verify the chosen method; (C) Hollow punch with three different diameters. Scale bar: (A)15 cm; (B-C) 5cm.

a *mata plong* (in Bahasa Indonesia), in three diameters (0.8 mm, 1.0 mm, and 1.5 mm) were used to extract the samples. Furthermore, the study was conducted in the Laboratory of Wood Formation and Quality Improvement, Faculty of Forestry, Universitas Gadjah Mada, Indonesia, from November 2019 – November 2020. The wood blocks and Panji mask replica used in this study were obtained from one art gallery in Bantul Regency, Daerah Istimewa Yogyakarta, Indonesia, namely Sanggar Peni.

The samples obtained were in a core form with a diameter of 0.8 – 1.5 mm and a length of 1 – 6 mm. The core samples were obtained from three sections of wood (transverse, tangential, and radial) by placing the hollow punch in the designated area and then punching it with a hammer until it entered the wood. If the wood isn't hard enough, the core sample is taken by pressing a hollow punch while rotating it. To take off the hollow punch, it is shaken and lifted from the wood, and then the core sample is pushed with a needle until it comes out. Furthermore, from one core sample, we can obtain three different sliced pieces, namely transverse, tangential, and radial sliced pieces.

The core samples were sectioned with sliding microtome (NS-31; Yamato Koki, Saitama, Japan) and freezing system (YD-III) with a thickness of 15-20 µm to obtain transverse, tangential, and radial sliced pieces. Furthermore, the sliced pieces were stained with 0.1% safranin solution, mounted on a glass slide, fixed with a resin (Entellan New; Merck, Darmstadt, Germany), and covered with cover glass. On the other hand, the wood fiber length sample was taken from a small piece of core sample (0.8 mm-1.5 mm in diameter) with a length of ±2 mm. The samples were macerated by boiling the core wood in Franklin solution, which is a mixture of glacial acetic (100%) acid and hydrogen peroxide (50%) (1:10) until it swells and disintegrates into fiber (Adimahavira *et al.* 2023).

Observations were conducted under the light microscope (Olympus BX51) with the digital camera (Olympus DP-60), and the images of transverse, tangential, and radial sections, as well as the images of wood fiber, were taken to measure the cell morphology using image analysis software (FIJI ImageJ). In addition, the images were observed to determine the selected parameters [Table 1] according to the IAWA List of Microscopic Features for Hardwood Identification (IAWA Committee 1989). The observed data were tabulated in order to explain the sampling attempts, items and the percentage of the items observed.

$$\textit{persentage item observed} = \frac{(\text{observed items})}{(\text{IAWA items})} \times 100\% \qquad (1)$$

where IAWA items were 44 items based on Table 1.

Moreover, data verification was performed to test the most effective sample collection method on cultural heritage objects, such as the Panji mask. The core sample was extracted from the part of the Panji mask that has a thicker part than the other, namely the nose or chin of the back of the mask, to minimize the damage to the object and not to distract the aesthetic of the object.

## Result and Discussion

The sample extraction with a hollow punch at each diameter has a different number of sampling attempts. The extraction with the fewest attempts was with a 1.5 mm hollow punch, which requires 1.7 to 2 sampling attempts, as shown in Table 2. Furthermore, extraction with a smaller diameter of hollow

| Anatomical Items | Anatomical Items |
|---|---|
| Growth rings [1, 2] | Axial parenchyma cell type/strand length [90 – 94] |
| Porosity [3, 4, 5] | Ray width [96 – 100] |
| Vessel arrangement [ 6, 7, 8] | Aggregate rays [101] |
| Vessel grouping [9, 10, 11] | Ray height [102] |
| Solitary vessel grouping [12] | Rays of two distinct sizes [103] |
| Perforation plates [13 – 19] | Ray cellular composition [104 – 109] |
| Intervessel pits: arrangement and size [20 – 28] | Sheath cells [110] |
| Vestured pits [29] | Tile cells [111] |
| Vessel-ray pitting [31 – 35] | Perforated ray cells [112] |
| Helical thickenings [36 – 39] | Disjunctive ray parenchyma cell walls [113] |
| Tangential diameter of vessel lumina [40 – 45] | Rays per millimetre [114 – 116] |
| Vessel per square millimetre [46 – 51] | Wood rayless [117] |
| Mean vessel element length [52 – 55] | Storied structure [118 – 123] |
| Tyloses and deposits in vessels [56, 57, 58] | Oil and mucilage cells [124 – 126] |
| Wood vesselless [59] | Intercellular canals [127 – 131] |
| Ground tissue fibers [60 – 64] | Tubes/tubules [132] |
| Septate fibers and parenchyma-like fiber bands [65, 66, 67] | Cambial variants [133 – 135] |
| Fiber wall thickness [68, 69, 70] | Prismatic crystals [136 – 143] |
| Mean fiber length [71 – 74] | Druses [144 – 148] |
| Apotracheal axial parenchyma [75, 76, 77] | Other crystal types [149 – 153] |
| Paratracheal axial parenchyma [78 – 84] | Other diagnostic crystal features [154 – 158] |
| Banded parenchyma [85 – 89] | Silica [159 – 163] |

**Table 1**.- Observed items of wood anatomical characteristic (total 44 items) according to the IAWA List of Microscopic Features for Hardwood Identification.

| WOOD SPECIES | | NUMBER OF OBSERVED ITEMS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.8 mm | | | 1.0 mm | | | 1.5 mm | | |
| | | X | T | R | X | T | R | X | T | R |
| Jaranan (*Lannea coromandelica*) | Sampling Attempts | 2 | 5 | 4 | 1 | 3 | 3 | 1 | 1 | 2 |
| | Observed | 35 | 37 | 37 | 37 | 36 | 36 | 37 | 39 | 39 |
| | Percentage | 79.5 | 84.1 | 84.1 | 84.1 | 81.8 | 81.8 | 84.1 | 88.6 | 88.6 |
| Pulai (*Alstonia* spp.) | Sampling Attempts | 5 | 5 | 6 | 3 | 4 | 5 | 2 | 2 | 2 |
| | Observed | 34 | 37 | 36 | 34 | 37 | 36 | 36 | 37 | 36 |
| | Percentage | 77.3 | 84.1 | 81.8 | 77.3 | 84.1 | 81.8 | 81.8 | 84.1 | 81.8 |
| Sengon (*Falcataria moluccana*) | Sampling Attempts | 5 | 6 | 5 | 4 | 5 | 3 | 3 | 2 | 2 |
| | Observed | 35 | 36 | 35 | 35 | 36 | 35 | 35 | 37 | 37 |
| | Percentage | 79.5 | 81.8 | 79.5 | 79.5 | 81.8 | 79.5 | 79.5 | 84.1 | 84.1 |
| Average of Sampling Attempts | | 4.0 | 5.3 | 5.0 | 2.7 | 4.0 | 3.7 | 2.0 | 1.7 | 2.0 |
| Average of Percentage | | 78.8 | 83.3 | 81.8 | 80.3 | 82.6 | 81.1 | 81.8 | 85.6 | 84.8 |

The percentage was based on the equation 1
X: the core sample obtained from transverse section, which from one core sample obtained x, t, and r sliced pieces
T: the core sample obtained from tangential section
R: the core sample obtained from radial section

**Table 2**.- he sampling attempts and percentage of features observed compared to IAWA List of Microscopic Features for Hardwood Identification feature used.

punch has more sampling attempts, such as sampling with a 0.8 mm hollow punch that requires 4.0 to 5.3 attempts and with a 1.0 mm hollow punch that requires 2.7 to 4.0 attempts. Based on the number of experiments, sample extraction with a 1.5 mm hollow punch has a smaller risk of damaging the object because it has the fewest number of sampling attempts.

The identification of wood species shows the differences in the sample size depending on the size of the hollow punch used [Figure 2]. In Figure 2, the tangential sliced pieces extracted by a 1.5 mm hollow punch have the largest size. The larger the sample taken, the more anatomical features are observed. This was supported by Table 2, where the sample extracted by 0.8 mm and 1.0 mm hollow punch had the ability to conduct 37 observed anatomical items on average. In comparison, the sample extracted by a 1.5 mm hollow punch had the ability to conduct 38 observed anatomical items on average. It needs to be emphasized that differences in just one anatomical feature affect the validity of the data in wood species identification. Furthermore, the observation continued by observing the differences of the sample extracted by 1.5 mm hollow punch in the three sections [Figure 3], and this showed that there was no big difference in the sample shape either extracted from the transverse, tangential, or radial sections. In this study, there are tears in the samples during the extraction process with a hollow punch, which prevents the sample from becoming completely round.

Moreover, with a 1.5 mm hollow punch, the samples extracted from the transverse section [Figure 3] contain 79.5% - 84.1% anatomical items, with 81.8% on average compared to IAWA [Table 2]. The samples extracted from the tangential section

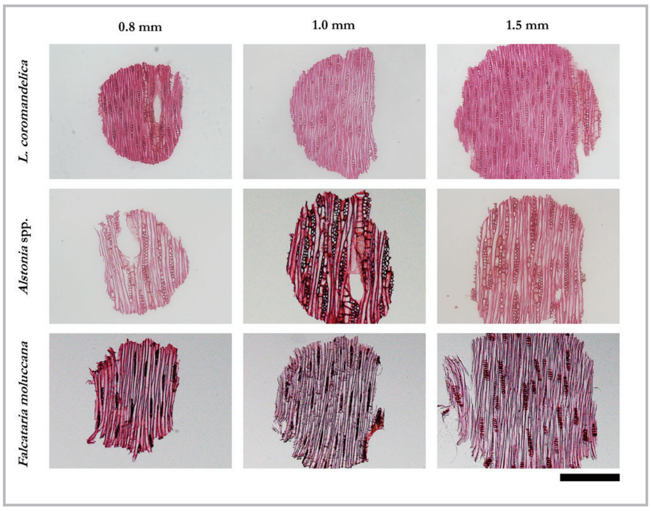


**Figure 2**.- The differences among samples obtained with three different diameters of hollow punch. Scale bar: 500 µm.

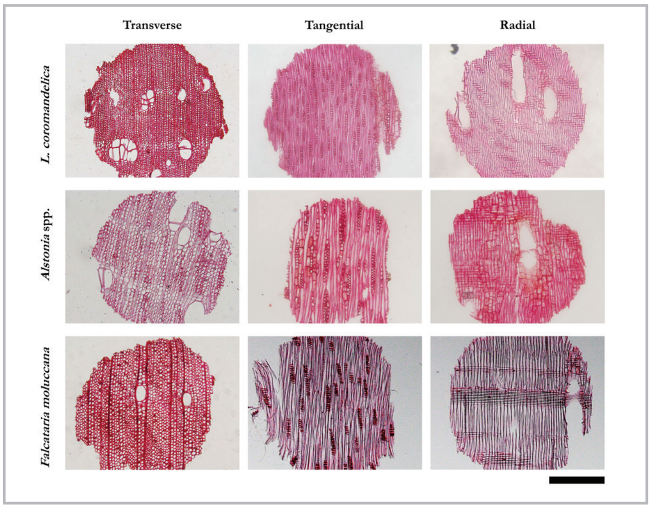


**Figure 3**.- Sample section extracted from three wood sections with a 1.5 mm hollow punch. Scale bar: 500 µm.

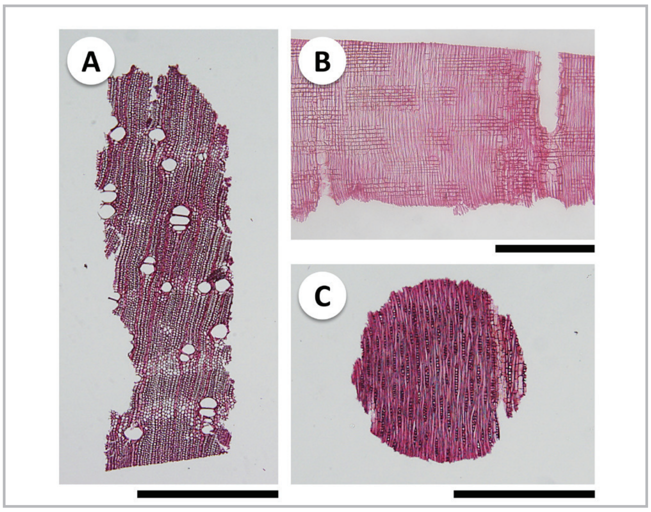


**Figure 4**.- (A)Transverse section; (B) radial sections; (C) tangential section of Lannea coromandelica taken by a 1.5 mm hollow punch on tangential section. Scale bar = 500 µm.

contain 84.1% - 88.6% anatomical items observed, with 85.2% on average. Meanwhile, the samples extracted from the radial section contain about 81.8% - 88.6% anatomical items, with 84.8% on average. Considering these results, it is known that the sample extracted at the tangential section will obtain more anatomical features to observe. This is shown in Figure 4, where the sample extracted by 1.5 hollow punch allows us to observe more features in the transverse and radial section [Figure 4 A and B].

Additionally, observation shows different results for each wood species. Based on statistical analysis (5%), the percentage of features observed among wood species is significantly different, with a value of 0.04. This showed that the different wood species had a significant influence on the percentage of items observed. Among other species, jaranan wood (*L. coromandelica*) had the most anatomical items to be observed, which might be because *L. coromandelica* had a higher specific gravity (0.40-0.75) than the other species, namely *Alstonia spp*. (0.30) and F. *moluccana* (0.23-0.49) (Insidewoood 2004; Martawijaya *et al.* 2005; Ogata *et al.* 2008), which makes the wood is pretty stable to be extracted by hollow punch. The different specific gravity of each wood influences the number of sampling experiment, namely sampling extraction on jaranan wood (*L. coromandelica*) has fewer attempts (1-2 attempts).

The most effective method, sampling with a 1.5 mm hollow punch at the tangential section, was applied to the Panji mask replica made from *L. coromandelica, Alstonia* spp., and *F. moluccana*. Furthermore, samples extracted from the *L. coromandelica* mask obtained 81.8% of anatomical items observed compared to those used in this study (44 items). In the *Alstonia* spp. mask, there were 81.8% of items observed, while the *F. moluccana* mask obtained 75% of items observed.

Moreover, the features, such as fiber length, were unobservable. This was due to the limited core sample obtained from the extraction. The limited size of the core sample was influenced by the difficulty of the extraction process, where the mask must be positioned in such a way to extract the sample with a hollow punch. The sample extraction from the *L. coromandelica* mask with a hollow punch was performed by punching the designated area at the back of the mask. For *Alstonia* spp. and *F. moluccana* mask, the sample was extracted by pushing while rotating the hollow punch in the designated area of the mask.

It needs to be emphasized that the proposed method is conditional. The method used in this study was applied to Indonesian tropical wood that is usually used for woodcraft (e.g., Panji mask), as mentioned above. This sampling method can be applied to wooden historical objects under several conditions, including being expected to have a certain specific gravity that penetrable for hollow punch, not having a thick coating, and not being an object that has been waterlogged for a long time. Furthermore, this method is expected to help in minimally invasive wood identification at a low cost.

## Conclusion

The data showed that sampling with a hollow punch is used as wood identification for cultural heritage with relatively minimal damage, and this is an alternative for sampling with the minimum invasive principle. Therefore, the most effective hollow punch size for this study was the 1.5 mm diameter, which was used to take samples at the tangential section, thereby obtaining the highest percentage of items observed and ensuring easier sampling, as well as sample slicing with a microtome.

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Artículo enviado 29/05/2023
Artículo aceptado el 21/10/2023



https://doi.org/10.37558/gec.v24i1.1217