



## Original Papers

# Historical anatomy: concept and approaches

João Carlos Ferreira de Melo-Júnior<sup>1,2</sup>

### Abstract

Wood is considered one of the natural resources most used by human cultures. Investigations on the wood species used by human societies throughout history arise separately in different research institutions and different areas of scientific knowledge globally. This work aims to establish and substantiate the concept of historical anatomy as a branch of wood anatomy, focusing on investigations into the cultural use of wood from a historical temporal perspective, with wood anatomy as its main analytical tool. Historical anatomy's interdisciplinary nature contributes to the convergence of multiple perspectives in studies of the cultural use of wood. This category presents four approaches: heritage, technological, environmental, and conservationist, which engage in dialogue with each other and deepen the understanding of the relationship established between human societies and the historical use of wood in their cultural systems.

**Key words:** cultural heritage, cultural use of wood, historical wood, society-nature, wood anatomy.

### Resumo

A madeira é considerada um dos recursos naturais mais utilizados pelas culturas humanas. Investigações sobre as espécies de madeira utilizadas pelas sociedades humanas ao longo da história surgem isoladamente em diferentes instituições de pesquisa e distintas áreas do saber científico ao redor do globo. Este trabalho objetiva estabelecer e fundamentar o conceito de anatomia histórica como um ramo da anatomia da madeira com foco nas investigações sobre o uso cultural da madeira em perspectiva temporal histórica, sendo a anatomia da madeira a sua principal ferramenta analítica. Sua natureza interdisciplinar contribui para a convergência de múltiplas perspectivas no campo do uso cultural da madeira. Esta categoria apresenta quatro perspectivas de abordagem: patrimonial, tecnológica, ambiental e conservacionista, as quais dialogam entre si e aprofundam a interpretação sobre a relação estabelecida entre as sociedades humanas e o uso histórico da madeira em seus sistemas culturais.

**Palavras-chave:** patrimônio cultural, uso cultural da madeira, madeiras históricas, sociedade-natureza, anatomia da madeira.

## Introduction

Wood is a vitally important renewable raw material in the world (Domínguez-Delmás *et al.* 2023) and the resource most used by human cultures (Melo Júnior 2022), having been used for thousands of years as tools, fuel, weapons, structures, and for recreation (Kisternaya & Kozlov 2007). The multiple uses of wood as an elementary raw material have boosted development and shaped the way of life of all human societies. Its different colors, textures, aromas, and densities make wood extremely dynamic in terms of its applicability, reverberating in the production of

cultural assets that represent different cultures and produce identity meaning. This material culture can be classified into a wide range of categories of use, such as adornments and clothing, handicrafts, dyes and pigments, ritual objects and statuary, recreation objects, musical instruments, fuel, weapons, structures, shelters and buildings, furniture, machinery and tools, means of transport, and household items (adapted to Melo Júnior *et al.* 2021b). Each category brings together a significant number of wood species, which have physicochemical and structural characteristics suitable for their purpose.

<sup>1</sup> Universidade da Região de Joinville, Department of Biological Sciences, Pos-graduate Program in Health and Environment, Pos-graduate Program in Cultural Heritage and Society, Lab. Wood Anatomy, Joinville, SC, Brazil. ORCID: <<https://orcid.org/0000-0002-6800-5508>>.

<sup>2</sup> Author for correspondence: [joao.melo@univille.br](mailto:joao.melo@univille.br)

The material culture produced using wood differs from other existing structures in wood by adding historical and heritage value (Cruz *et al.* 2015). The first records in the literature on the cultural use of wood by historical societies deal with engravings of animals carved in wooden blocks that allowed describing aspects of the natural history of certain species of birds (Beilby 1804) and quadrupeds (Beilby 1807). Even in the 19th century, treatises on the art of woodcutting were written, including its history and techniques (Jackson 1861; Linton 1882; Woodberry 1883). During the first half of the 20th century, studies relating the properties of wood to its use in constructive structures and shelters were most abundant, with emphasis on the physical and mechanical characteristics of interest to civil engineering (Parkinson 1904; Fletcher & Snow 1934), on the construction techniques of wooden buildings (Kniffen & Glassie 1966), and on other technological applications of wood (Tiemann 1942; Panshin *et al.* 1950), as well as the problem of preventing the degradation of wooden structures by xylophagous organisms and humidity (Cartwright & Findlay 1946; Wood 1954).

In the second half of the 20th century, during discussions about the emergence of socio-environmental problems already triggered by many countries, new approaches to the cultural use of wood were added to the scenario of studies on constructive structures (Weimer 1983). In this context, studies were added that problematized the reflection of wood use on the conservation of forest landscapes (Clawson 1979; Rackham 1983; Whitney 1987) and the overexploitation of timber species by sawmills (Menezes & Guerra 1998). Still in this period, in a less expressive way, there are records of studies on the use of wood in the imperial naval tradition (Hutter 1986), in Christian religious art (Ono *et al.* 1996), and in indigenous art (Lisboa & Coirolo 1995), culminating in the publication of principles for the conservation of historic wooden structures (ICOMOS 1999).

While historical buildings remain a key focus for studying the cultural use of wood, especially from a technological perspective, the early 21st century has seen a shift toward research that fosters a meaningful conversation with the cultural heritage field and explores how various societies today engage with wood in diverse cultural contexts. Thus, studies can be cited on the cultural use of wood in indigenous handicrafts and utensils (Lisboa & Coirolo 1995; Melo-Júnior *et*

*al.* 2013, Machado *et al.* 2018; Santos *et al.* 2022), sacred statuary (Ono *et al.* 1996; Lipshchitz 1998; Harvey 2009; Marchiori & Schulze-Hofer 2009, 2010; Almeida *et al.* 2011), ritual objects (Giachi *et al.* 2016), musical instruments (Angyalossy *et al.* 2005; Olaoye & Oluwadare 2021; Quintavalla *et al.* 2022), weapons (Western & McLeod 1995), structures such as foundations and bridges (Boschetti *et al.* 2014; Macchioni *et al.* 2016; Pagani *et al.* 2022; Silva *et al.* 2022), shelters and buildings (Argentina 2003; Marchiori & Schulze-Hofer 2008; Andreacci & Melo Júnior 2011; Calicchio *et al.* 2012; Fernandes 2012; Melo Júnior 2012b; Diodato *et al.* 2013; Francesco *et al.* 2013; Melo-Júnior 2017; Gonçalves *et al.* 2019; Kolář *et al.* 2021; Mertz 2021; Pscheidt & Melo Júnior 2021, 2022; Wächter & Grabner 2021; Melo Júnior *et al.* 2022b; Mendoza *et al.* 2022; Hoffmann *et al.* 2023; Macchioni *et al.* 2023; Zwerger 2023), furniture (Pagani *et al.* 2018; Melo Júnior 2012a), machinery and tools (Lange 2017; Macchioni *et al.* 2017; Melo Júnior 2012a), means of land transport (Melo Júnior & Boeger 2015), traditional boats (Giachi *et al.* 2003; Bardet *et al.* 2004; Gonzaga 2006, 2010; Gaspar & Ferreira 2011; Andrade *et al.* 2016; Melo-Júnior & Barros 2017a, 2017b; Orofino *et al.* 2017; Melo-Júnior *et al.* 2019a, 2019b; Krueel *et al.* 2021; Melo-Júnior *et al.* 2021a; Melo-Júnior 2022), and household items (Melo-Júnior & Boeger 2015), as well as studies that relate the transport of wood between different geographic regions and countries (Almeida *et al.* 2006; Silva *et al.* 2020; Johann 2021), to the extensive and historical exploitation of wood resources on the conservation of species (Hoff & Simioni 2004; Maioli *et al.* 2020; Melo-Júnior *et al.* 2022a) and forest management practices (López-Bultó *et al.* 2023).

There is also a growing number of works that evaluate the biodegradation that occurs over time in wooden cultural objects, aiming at the application of conservation and preservation methods that maintain the historical integrity of the cultural heritage and are capable of maintaining the connection between present and past (Unger 2001; Kisternaya & Kozlov 2007; Nilsson & Rowell 2012; Cruz *et al.* 2015; Larsen & Marstein 2016).

In a timeless perspective, the point of convergence between such studies is wood as a raw material and, to a certain extent, its approximation as a taxonomic entity with different levels of reliability. This is especially the case when the morphological characteristics of the trees have

been eliminated, and the supposed species is only suggested by popular practices through sensory characteristics (Zenid & Ceccantini 2007). On the other hand, the great diversity of approaches adopted reflects different interests about the applicability of wood and, therefore, distances them from the dialogue on cultural use. With the improvement of the microscope, starting in the 20th century, the anatomy of wood has served indistinctly as a support for this research, proving to be a crucial tool for the structural characterization of wood and identification of wood species.

Studies on historical woods allow, when taking an interdisciplinary perspective, to answer questions about the cultural past, the forms of organization and technological skills of human societies over time, and their practices of managing nature (Domínguez-Delmás *et al.* 2023). Thus, the present work aims to conceptualize and substantiate a new research category inside wood anatomy (historical anatomy) and its respective approaches. Having wood anatomy as its main analytical tool, this interdisciplinary approach aims to contribute to the convergence of multiple perspectives in the field of the cultural use of wood.

#### The emergence of an interdisciplinary perspective

Wood, as a forest resource, is widely studied across numerous scientific disciplines due to its presence in diverse environmental and sociocultural contexts. Following the Cartesian logic of Western science construction, we encounter studies focused on specific aspects of wood, as can be observed in classic studies in Botany, Forestry Engineering, Civil Engineering, and Materials Science (Cruz & Nunes 2005; Evert 2006; Paula & Alves 2007; Pereira 2013). Due to wood's significant appeal as a raw material for shelter construction and other technological uses, the anatomy of wood has long been associated with descriptive and physical-mechanical studies, leading to important reference works (Mainiere & Chimelo 1989; Coradin *et al.* 2010). However, these areas do not inherently address the cultural-heritage nature of interactions between humans and wood.

In understanding the evolutionary processes of the environment and plant species themselves, wood has always been a key element, especially in the fields of Paleobotany (Stewart & Rothwell 1993) and Dendrochronology (Hughes 2002). Considering the vast time spans addressed by Paleobotany, fossil wood, situated within

a geological framework, exists beyond the tangible reach of human experience. When aiming to understand the way of life of past human populations and their relationship with biological diversity, significant theoretical and methodological advances were made by Archaeological Science (Gremillion 1997), although its major interface has historically been substantiated by human and faunal skeletal remains, as well as rocks and other materials worked by humans (Prous 1991; Neves 1996).

From the science that studies past human populations, Archaeobotany emerged, later developing into a discipline dedicated to the study of past human cultures and their interaction with the plant world (Schiffer 2014). Its investigative foundation considers any parts or components of plants, including micro remains (pollen, spores, crystals, and phytoliths) and macro remains (seeds, fruits, fibers, and wood) obtained from archaeological sites (Hastorf & Popper 1988). From this broad perspective, Anthracology arises as a discipline related to the analysis and interpretation of carbonized macro plant remains, with an emphasis on carbonized wood (charcoal) for the reconstruction of paleofloras and paleoenvironments (Vernet 1990) or for understanding the way of life of prehistoric populations (Pearsall 1983).

In just over half a century, the specific nature of Anthracology has propelled specialized terminologies and protocols into the archaeological context (Pearsall 2000), gaining strength in Brazilian science in the early 21st century (Scheel-Ybert *et al.* 2006). These efforts represent methodological advances in botanical remains recovery techniques, allowing for expanded qualitative-quantitative analyses of plant use, although interpretations are strongly grounded in ethnobiological approaches of current indigenous or traditional populations (Ceccantini 2001).

From a historical perspective, the widespread use of plants is encompassed by Ethnobotany, which investigates the relationships between plants and contemporary human cultures, including the use of plants in medicinal practices, rituals, food, and other cultural aspects (Albuquerque 2002). This science originates from Ethnobiology and its counterpart, Ethnozoology, within a context where the primary interest was the economic value of indigenous products derived from plant or animal materials (Clement 1989). Like archaeobotany, except for the temporal perspective, Ethnobotany has a precise

theoretical-methodological framework, covering extremely broad aspects of plant use by human populations (Ludwig & El-Hani 2020).

There are gaps in the scientific literature when culturally used wood becomes the central object of research, evidenced by the lack of specialized collection protocols that comply with cultural heritage protection standards, the absence of guidance on the treatment and curation process of samples, as well as the lack of standardization of terminologies. On the other hand, countries with a strong tradition in the study of culturally used woods, such as Italy, have developed specialized protocols and heritage laws (UNI 2004). Therefore, the present approach aims to advance a terminological proposal considering the multiple contributions from various knowledge areas that have wood as an object of investigation and, thus, demonstrate how anatomical studies on culturally used woods have evolved and require standardization. Additionally, understanding that biodiversity data are generally isolated (Waide *et al.* 2017), it is important to combine knowledge and tools from different disciplines to obtain a more accurate representation of nature (Carvalho *et al.* 2023) and its forms of use, enhancing our understanding of tree biology and forest ecosystems (Baas & Wheeler 2011). From this viewpoint, the principle of interdisciplinarity not only transcends mere parallel information exchange but also fosters the merging of complementary knowledge (Pombo 2008), leading to the development of unique methodologies and terminologies.

### Wood anatomy and its categories

Wood anatomy presents different analytical and interpretative categories. The most elementary category, known as descriptive anatomy, addresses the description of the xylem tissue aimed at the structural characterization of a given species and also at the identification of species of economic interest. Descriptive anatomy presents two approaches: macroscopic and microscopic. The first evaluates sensory and anatomical characteristics that require little magnification, being widely used in the identification and inspection of commercial wood (Mainieri & Chimelo 1989; Coradin *et al.* 2010; Botosso 2011); while the second characterizes attributes of the tissue and cells that make up the wood, allowing safer identifications (Record e Hess 1943; Metcalfe & Chalk 1950; Détienne & Jacquet 1983; Wheeler *et al.* 1989; Richter *et al.* 2004; Ruffinatto

*et al.* 2015). The category of ecological anatomy (Carlquist 1977, 1989) seeks to understand the relationship between anatomical characters and the various environmental factors, allowing the observation of trends in structural variation. According to various studies, wood can provide information and characteristics that aid in the systematization of groups and the understanding of environmental factors that exert selective pressure on plants. Thus, the ecological wood anatomy can be employed to determine evolutionary trends within some or all representatives of a flora (Baas *et al.* 1983; Baas & Carlquist 1985; Baas & Schweingruber 1987; Barajas-Morales 1985; Alves & Angialossy-Alfonso 2000, 2002; Barros *et al.* 2006) or to comprehend anatomical alterations among specimens of a specific taxon, typically at the same hierarchical level, in the face of environmental heterogeneity (Carlquist 1988). The ecophyletic anatomy category integrates phylogenetic analyses and ecological adaptive studies to understand secondary xylem evolution (Dickison 2000).

### Historical anatomy: definition, assumptions, and approaches

How does historical anatomy differ from other categories of wood anatomy? What is the scope of historical anatomy, its assumptions and approaches?

Historical anatomy is defined as an interdisciplinary category of wood anatomy that studies woods in cultural use by historical human societies. For the analysis and interpretation of the investigated object (wooden artifact), it is necessary to build an integrative dialogue between different areas of scientific knowledge, systematized in three steps: (1) space-time contextualization, (2) wood anatomy, and (3) biological contextualization. The steps are fluid and can be reordered as needed. Figures 1 and 2 demonstrate how the historical anatomy is systematized and how different themes and areas of knowledge are interconnected to enable the interdisciplinary interpretation of cultural wood. The investigated wooden cultural artifacts can be accessed in different conditions, such as historical sites, museum collections, collections in traditional communities, or in direct contact with master carpenters and artisans.

The first step is characterized by using oral, documentary, bibliographical, and narrative sources that allow the wooden artifact to be contextualized within its socio-historical and cultural system,

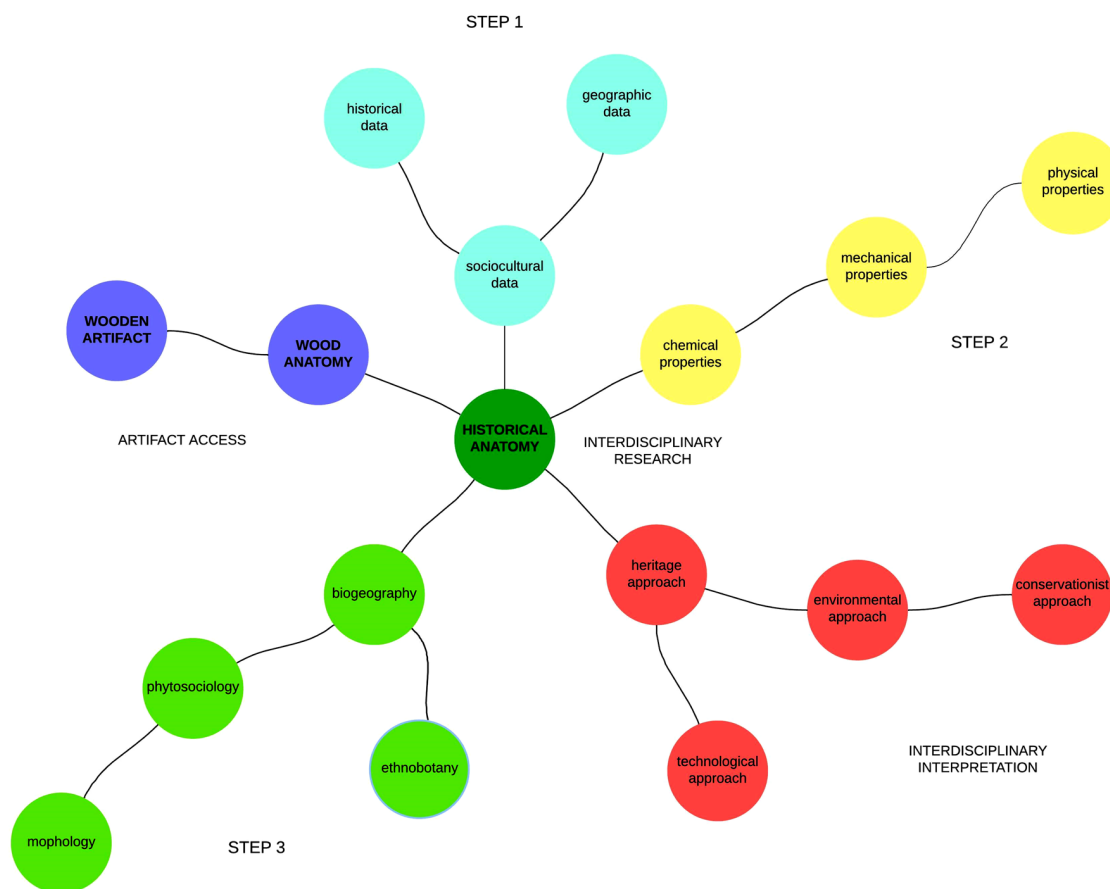
positioning it in historical and social time and geographic space, also including related aspects to the associated natural and cultural landscapes.

The second step operates the microscopic analysis of the artifact in wood, following the conventional protocols in wood anatomy that lead to the taxonomic determination. The aim is to reach the lowest possible taxonomic level. At this step, physical-mechanical and chemical tests of the studied wood may also be included. Identification is carried out by comparison in reference wood collections (xylotiques) and specialized databases.

The third step concerns the biological nature of the taxon identified in the second stage, giving the wooden artifact an identity capable of producing a sense between the biological and the cultural. At this stage, the identification result is supported by biogeographical and phytosociological data about the taxon indicated by the anatomy and correlated with processes of selection or fortuitous use of wood and wood transport between phyto-geographic

regions and countries. Morphological dimensional information of the tree and ethnobotanical indicators, when available, support the category of use for which the wood was destined.

The interdisciplinary interpretation of the data, generated through the multidisciplinary confluence of information on wood for cultural use, allows the historical anatomy to be divided into four distinct approaches: heritage, technological, environmental, and conservationist. The heritage approach problematizes the cultural field by accessing memories, legacies, knowledge, and actions linked to the material and/or immaterial dimensions of the artifact produced in wood by human societies; it contributes to expanding information on the registration of cultural assets belonging to museological collections, collections, sites, and other assets (listed or not by heritage management bodies); and supports actions to restore wooden cultural assets and their conservation in the face of biodeterioration. The technology relates the

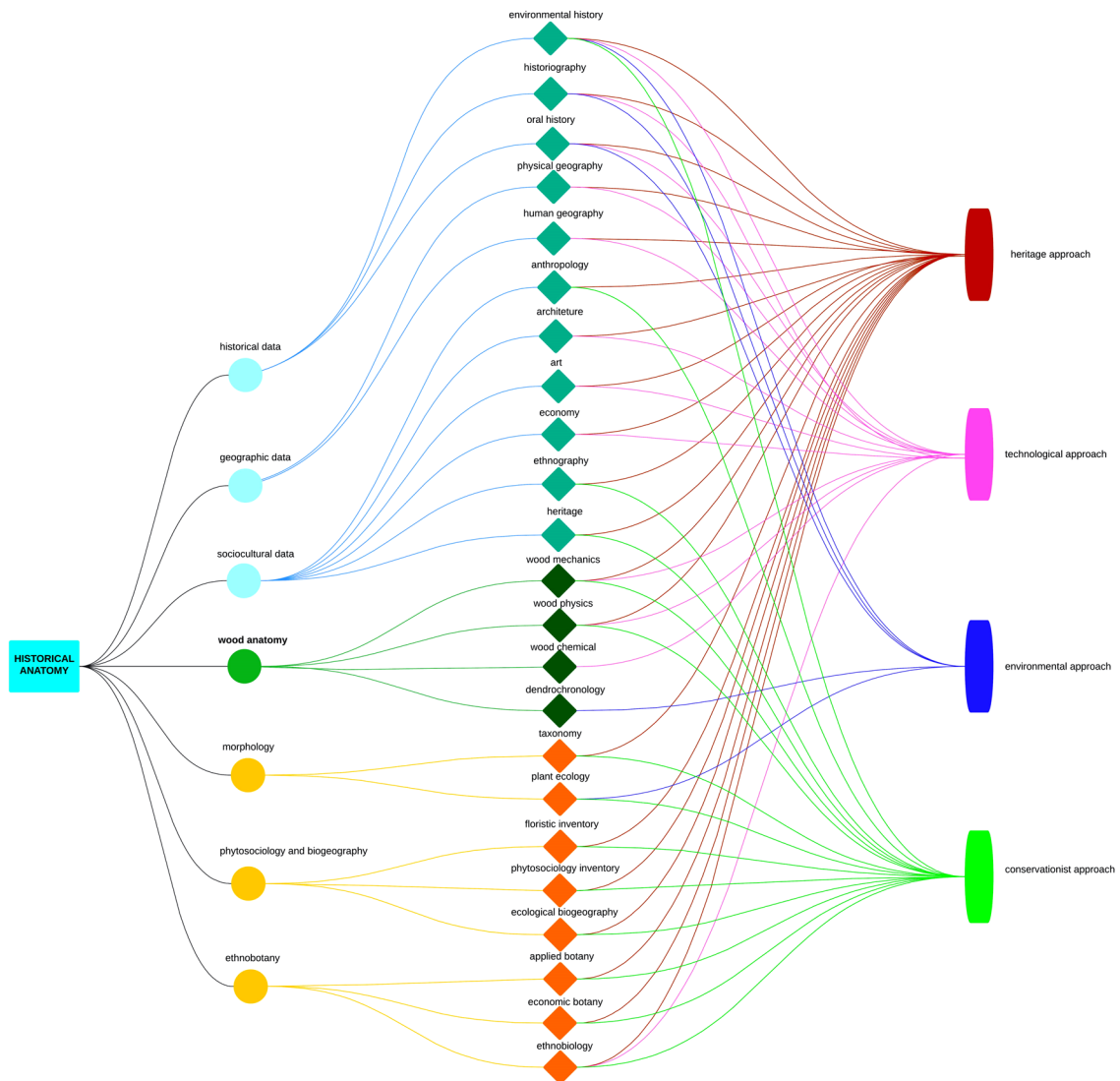


**Figure 1** – Map of the interdisciplinary systematization of historical anatomy and its approaches.

processes of selection or fortuitous use of wood permeated by the physical-mechanical and chemical properties and dimensional aspects of the species. The environmental approach makes it possible to understand, through the plasticity of certain attributes of the wood or dendrochronological markers, the conformation of the environment at the time the wood was harvested and the resulting transformations over time, sometimes triggered by climate changes. The conservationist evaluates the possible impact of the cultural use of wood on the natural populations of the species, generating subsidies to understand the current state of ecological conservation of species and forest ecosystems

in areas historically of significant anthropic pressure, in addition to establishing an interface with the conservation of biodiversity through ethnoknowledge and sustainable development.

Studies on the cultural use of wood have increased in recent decades, setting up a strand of scientific investigation that has aroused the interest of researchers from multiple areas of scientific knowledge. This interest is largely directed towards the anatomy of wood in relation to traditional knowledge. Frequently, this research explores how the woody flora is utilized in creating cultural goods associated with diverse human societies.



**Figure 2** – Integration of themes and areas of knowledge for interdisciplinary interpretation in historical anatomy.

The understanding that a large part of the material culture produced by traditional communities results from the appropriation of resources offered by nature, mainly wood as a raw material, makes it possible to comprehend the symbolic or real meaning of the relationship established between these communities and the forest, as well as allowing the mapping of memories and knowledge related to trees of human interest.

The multiplicity of uses of wood in cultural assets and the extensive array of woody species utilized by different human societies over time highlight the intimate relationship between human peoples and wood around the world. The results from historical anatomy arise from the intersection of information from different areas of scientific knowledge, with emphasis on the anatomy of wood. The generated information allows for recording the knowledge produced by human societies about the selection and cultural and technological application of wood expressed by different categories of wood use. Therefore, wooden heritage, which faithfully represents cultural aspects and material or symbolic heritage, is capable of attributing other meanings to biodiversity and its conservation. In addition, such studies can and should dialogue with the important fields of management, conservation and restoration of cultural heritage in wood.

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### Data availability statement

In accordance with Open Science communication practices, the authors inform that all data are available within the manuscript.

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