forests

Systematic Review

Adding Value to Wood-Based Products: A Systematic Literature Review on Drivers

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Abstract: The term "added value" is frequently used by stakeholders in the forest wood sector. However, beyond its intuitive meaning, what does "added value" mean in economics, and what are the main ways of adding value to wood-based products? To answer these questions, a theoretical framework of the concept of "added value" and an overview of its main applications within wood supply chains are provided. Subsequently, the results of a systematic literature review are reported. A total of 1974 primary research articles published in English in the last decade were collected from the Scopus and Web of Science databases. The main objectives were to understand how the "added value" concept is addressed, determine which wood-based products are studied, identify how value is added, and ascertain the main consequences. The analysis of the 111 selected articles showed that the term "added value" is often used as a label rather than a clearly defined concept. Improved production processes and the valorisation of raw materials were found to be the main methods of adding value to wood-based products, while environmental benefits emerged as the most frequent objective. The findings may serve several purposes, such as identifying research needs, guiding industrial innovation, and informing policy makers, helping to implement measures that really benefit wood supply chains. Building on this study, future research could explore how added value is perceived and implemented by forest enterprises, wood industries, policymakers, and other stakeholders. This would provide a broader reference framework for applying the concept of added value.

Keywords: economic value; opportunities; solid wood; valorisation; value chain; wood-based composites; wood-based products

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1. Introduction

Whether used by academics, industry agents, members of institutions, or other stakeholders, terms such as "added value", "value chain", and "valorisation" are frequently encountered in the wood sector. Yet, they tend to be used only as labels, without further clarification. This can be attributed to the fact that such terms have a positive, intuitive meaning that contributes to their use as buzzwords. However, the economic concept of added value is far from simple and encompasses several aspects, ranging from the competitive advantages associated with it to how it is interpreted by managers and customers [1].

This review addresses the strategic importance of adding value to wood-based products. The analysis begins with a theoretical framework of the concept of "added value" from an economic perspective and then moves on to relevant cases in wood supply chains. Subsequently, the results of a systematic review are presented. The review was structured such that it would allow us to examine how the scientific literature on wood-based products addresses the concept of added value, which products are considered, what technologies and methods are used to enhance value, and what the key consequences are (see Section 1.3). These aspects are interconnected by two main affordances. First, they provide a comprehensive overview of the primary drivers influencing the topic, offering a valuable foundation for future research. Second, they assess how the scientific literature supports the implementation of added value throughout wood supply chains. A lack of attention to this issue could limit tangible impacts, which may be particularly crucial for certain supply chains, such as those operating at a local level or relying on low-quality wood raw material.

This knowledge can guide the definition of research needs, targeting the development of wood-based products and the study of their properties. It can also help enhance the competitiveness of wood industries through diversification, innovation, and the improvement of established processes and products. Finally, it can support interaction with policy makers, helping to implement measures that can generate added value and have a positive impact on stakeholders.

Table 1 lists the abbreviations used throughout this paper.

Table 1. List of abbreviations used.

Abbreviation	Terms
CLT	Cross-Laminated Timber
DfD	Designed for Disassembly
EVA	Economic Value Added
GLT	Glue-Laminated Timber
GVC	Global Value Chain
OSB	Oriented Strand Board
PICO	Population, Intervention, Comparison, and Outcome
PERVAL	Perceived value
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SMEs	Small and medium-sized enterprises
RBV	Resource-based view
SFO	Sustainable Forest Operations
TCV	Theory of consumption values
WPC	Wood–plastic composites
W-PU	Wood–polyurethane

1.1. Added Value: A Theoretical Overview

Before we define added value, it is essential to define the concept of value itself, regardless of the specific sector and products. Historically, value has been formally divided into two primary components: exchange value (monetary value) and perceived utility value [2]. Over the centuries, scholars have provided various definitions of value [3] in accordance with the prevailing economic theory of the time, resulting in a lack of a clear and unambiguous definition [4]. In business strategy studies, value has been defined based on the buyer's willingness to pay [5]. In pricing studies, since the late 1980s, value has been characterised by a two-way definition that considers both the utility derived from the purchase of a good and the sacrifices incurred to obtain it [6]. In this case, value is defined as potential before purchase and actual afterwards [7]. In consumer behaviour studies, value has been defined in terms of desirability and necessity [1].

These latter aspects introduce another concept: perceived value. This has been analysed in the literature through various approaches [8], among the most relevant of which is the theory of consumption values (TCV) proposed by Sheth et al. [9]. This model explains the consequences of consumer choice, identifying five different values: functional (i.e., the tangible attributes and functional role of a product), social (i.e., the sense of belonging to one or more social groups), emotional (i.e., the inspiration generated by affective ties and feelings), circumstantial (i.e., contextual factors influencing consumption), and epistemic (i.e., the ability to satisfy novelty or curiosity). Based on TCV, Sweeney and Soutar [10] later developed a multiple-item scale for measuring perceived value (PERVAL).

In this study, we consider the formation of a product's sale price based on consumer-perceived value rather than production costs. We therefore use Lind's [11] definition of added value as a starting point: "The difference between the selling price of a good and its production cost". However, it should be emphasised that a change in production processes, such as process or product innovation, does not necessarily lead to an increase in added value [12] unless these changes are perceived as valuable by the consumer [13]. Levitt's [14] concept of "augmentation" is emblematic in this respect: the addition of features that the consumer does not think about may not enhance perceived value if these extra features are not utilised or recognised. In some cases, these features may even diminish the previous offering's value [15]. Conversely, in the case of customer delight, modifications that exceed the consumer's basic expectations can generate a positive perception, adding value by increasing willingness to pay and the sale price [16].

Added value can be modified by expanding the perceived benefits or reducing perceived sacrifices associated with purchasing a product [15,17]. Benefits encompass a multidimensional construct, including functional, economic, and social aspects, while sacrifices refer to both the effort required at the time of purchase and the perceived risks associated with the long-term implications of owning durable goods [18,19]. Additionally, as mentioned earlier, intangible assets, such as knowledge, relationships, and innovations, can contribute to added value [20].

A distinction must be made between the terms "added value" and "value-added", as they are often mistakenly used as synonyms in the literature. The latter, however, has a specific meaning in accounting [21], particularly in relation to performance indicators, such as Economic Value Added (EVA) [22], which measures a firm's value creation.

Value creation occurs when companies start delivering value to clients [23]. This concept forms the basis for business model development and, according to De Martino [24], can be analysed from two perspectives: the supply-chain one, based on shareholder theory [25,26], in which firms create value for consumers while maximising shareholder interests, and the sustainability-based perspective, based on stakeholder theory [27,28], in which firms extend responsibility to employees, suppliers, and society at large.

Within the supply chain perspective, there are two possible theoretical foundations: the resource-based view (RBV) [29], which attributes value creation and competitive advantage to a firm's internal capabilities and resources; and Porter's [30] generic strategies, which associate value creation and competitive advantage with specific actions, such as cost reduction (i.e., cost leadership) or the differentiation of goods.

In recent decades, the concept of value creation has extended beyond the individual firm to encompass the entire value chain, including suppliers and consumers. This evolution has introduced new value concepts such as value constellation [31], value co-production [32], and shared value [24,31]. In this regard, another perspective on added value comes from game theory; in particular, it relates to examining a firm's position within the value chain and the market. A firm's added value, and thus its competitive advantage, is determined by the difference between the total value created in the market, including its contribution, and the total value created in its absence [33].

1.2. Adding Value to Wood-Based Products

The opportunities for adding value to wood-based products can be examined by considering the different stages of their life cycles [34]. With reference to the main methods of adding value discussed in Section 1.1, the following overview starts from forest growth and proceeds to address forest operations, first and second processing, marketing, performance in end uses, and recycling, reuse, and disposal. This presentation style is intended to outline the main drivers while presenting some relevant recent examples.

Regarding forest growth, silvicultural practices are crucial for creating or maintaining the value of wood as a raw material and can have several purposes such as favouring more valuable species, optimising the yield of specific assortments, and ensuring a constant supply over time [35]. Silviculture affects multiple wood characteristics related to mechanical and aesthetic quality, including dimensions, growth ring width, knot size, and grain slope. The presence and extent of these characteristics determine the suitability of raw timber for different products and uses, leading to significant differences in assortment value. For example, sweet chestnut silvicultural techniques aimed at reducing the occurrence of ring shake are essential to producing logs suitable for structural beams, thereby limiting the amount of wood relegated to lower-value uses such as poles or tannin extraction [36]. Similar considerations apply to arboriculture, where proper management can optimise plantations' profitability, especially when logs are intended for rotary cutting or veneer slicing.

The certification of sustainable forest management is another element that can enhance the value of wood-based products by improving sustainability credentials and increasing trade appeal. Various studies have demonstrated that forest certification can yield several benefits, particularly in terms of access to new markets, export competitiveness, and corporate image [37]. However, some cases have reported unsatisfactory results from forest certification, including issues such as unmet managerial expectations, trade barrier effects, and low or non-existent premium prices acknowledged by the market [38]. Therefore, the actual economic value added by forest certification should be evaluated on a case-by-case basis, depending on specific market contexts.

Forest operations play a crucial role through the identification and preservation of the quality of the timber assortments to be extracted. According to Marchi et al. [39], quality optimisation is one of the pillars of the modern concept of Sustainable Forest Operations (SFOs), together with environmental, ergonomic, economic, and societal considerations. In particular, quality should be optimised through the correct assessment of the assortment and its optimal bucking and preserved by operations aimed at ensuring future yields. The level of mechanisation and the competence of forest operators are key factors, as they can impact timber value and productivity by tens of percentage points [40].

Operator competence is also fundamental during the first and second processing of wood products [41]. Its influence is particularly significant in complex manufacturing processes, where production equipment also plays a crucial role. A relevant example is the Industry 4.0 approach, which focuses on implementing digital productive technologies, such as Smart and Cloud-Based Manufacturing, particularly within a circular economy framework [42]. In fact, the concept of added value extends beyond production processes to the entire organisation. In this regard, ISO 9001 [43] explicitly states that its process-based approach, founded on the plan–do–check–act cycle and risk-based thinking, enables organisations to consider processes in terms of added value.

Regarding wood products, added value can be categorised into two broad areas. The first involves maintaining or enhancing the inherent properties of wood. For example, strength grading allows timber to be used in structural applications, while surface treatments enhance its aesthetic appeal. The second involves adding new properties to wood and its derivatives. Examples include modification processes that improve the natural durability of low-durability wood and the layered composition of thermal insulation panels. Such strategies are often essential to enable wood to compete with alternative, higher-performing materials, ultimately unlocking the environmental benefits associated with its use. Notably, adding value is not necessarily linked to innovation, although the two concepts are frequently associated. For example, Oriented Strand Board (OSB) and other wood-based panels are specifically designed to add value to low-quality wood, and, at the same time, they are well-established products.

Marketing is another key factor in adding value to wood-based products. Large companies in the wood sector typically have well-structured marketing departments focusing on modern strategies for product valorisation, customer satisfaction, and brand perception [44]. In contrast, small and medium-sized enterprises (SMEs) often have underdeveloped marketing strategies [45]. Improvements can be pursued at various levels within SME supply chains. Some examples include increasing profit efficiency by selling timber at more advanced processing stages, improving promotional materials and online presence, and adopting more analytical approaches to market segmentation and customer care.

In recent years, sustainability has become a central theme in the marketing of wood-based products. Many promotional materials and company websites emphasise sustainability over the technical properties and intended uses of wood products. Furthermore, unlike many other materials, wood's aesthetic appeal and the cultural traditions associated with its use can be effectively leveraged in marketing strategies. These aspects are frequently strong selling points for wood products across diverse sectors, ranging from construction and furniture to specific markets such as acoustic guitars [46].

Finally, end-of-life management and resource recovery contribute markedly to adding value by reducing environmental impacts. Wood's biodegradable nature provides an intrinsic competitive advantage over many other materials. However, proper planning is required for these final stages, both at the individual product level and for entire structures, as seen in the emerging application of the Designed for Disassembly (DfD) concept in timber buildings [47].

Product design can also optimise the use of recycled wood as a secondary raw material, particularly by minimising the use of chemicals and adhesives. The increasing importance of recycled wood in the global market is paramount for reducing pressure on natural forests, given the growing demand [48]. The circular economy approach and the cascading use of wood are indeed essential strategies for optimising resource uses, reducing waste, and minimising environmental impacts. A notable example is the increasing incorporation of recycled wood in the wood-based-panel industry [49].

1.3. Research Questions

A systematic review was conducted to analyse how the concept of "added value" is considered in recent scientific articles on wood-based products. The primary aim was to answer the following research questions:

Q1: "How do scientific papers on wood-based products address the concept of 'added value'?"

Q2: "What categories of wood-based products are being studied?"

Q3: "What technologies or methods are used to add value?"

Q4: "What are the main consequences of adding value to wood-based products?"

These questions were considered key for exploring the multifaceted nature of added value related to wood-based products. By answering them, we aim to provide a deeper understanding of the different dimensions through which value is addressed in scientific articles.

2. Materials and Methods

2.1. Search Strategy

This review adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [50] guidelines. The rationale for this review in the context of existing knowledge is presented in Sections 1.1 and 1.2, while the objectives are reported above (Section 1.3) as research questions. The following subsections describe the systematic review process.

A literature search was conducted between November 2024 and December 2024, using the Scopus Elsevier and Web of Science databases. The search strategy focused on wood-based products' characteristics and added value. Relevant keywords were identified and combined using Boolean operators (AND, OR) and wildcards (*). Specifically, the following research string was used: TITLE-ABS-KEY ("wood" OR "wood-based" OR "wood based") AND TITLE-ABS-KEY ("value-added" OR "add value" OR "adding value") AND TITLE-ABS-KEY ("valorization" OR "optimization" OR "properties" OR "characteristic*" OR "improvement" OR "advanc*" OR "develop*") AND NOT ALL FIELDS ("bamboo" OR "palm"). The search was restricted to the "TITLE-ABS-KEY" field to ensure a focused exploration of relevant articles was conducted. Furthermore, the terms "bamboo" and "palm" were excluded to avoid results that could divert from the main research scope.

2.2. Eligibility Criteria

Eligibility criteria were determined using the PICO framework to ensure a systematic formulation of the research hypothesis and methodically establish the criteria listed in Table 2. Studies that did not meet the PICO criteria were excluded. In case doubts were raised, full texts were screened to determine inclusion/exclusion. Additional inclusion criteria were added: (i) written in English, (ii) open-access primary research articles, and (iii) published within the last 11 years (this time span was chosen to provide a picture in line with current research trends, technological advancements, and testing methodologies).

Table 2. PICO elements.

PICO Element	
Population (P)	Scientific papers on wood-based products
Intervention (I)	Elaboration of the concept of "added value"; innovative technologies or methods used to add value
Comparison (C)	"Added value" is mentioned but not elaborated
Outcome (O)	Definitions of the concept of "added value"; assessments of the different products studied and the approaches to adding value

2.3. Data Extraction

Article selection was carried out through an independent evaluation process by two researchers who worked independently. The selection process consisted of full-text reading. Data extraction was performed using a Microsoft Excel (Microsoft Corp., Redmond, WA, USA) spreadsheet, where the following variables were collected from full-text articles: ID; title; author(s); year of publication; added value concept: label or elaborated; where value is added; wood-based products; product category; methods used to add value (relating to production processes, valorisation of raw material, product technology, sustainability, economic aspects, and social aspects); aspects of added value; and outcomes of adding value. To facilitate data extraction, the above variables were grouped into categories, which were then used to analyse the results (Table 3). The risk of bias for each included study was assessed by the researchers via double-checking after their independent evaluation process.

Table 3. Extraction table: variables and categories.

Variables	Categories
ID, title, author(s), year of publication	N/A
Added value concept: label or elaborated	"Yes", "No", "Not explicitly"
Where value is added	"Wood-based product", "Wood sector"
Wood-based products	"Biochar/Biomass", "Packaging", "Paper", "Pellet", "Solid wood", "Wood extractives", "GLT and CLT", "Wood-based panel", "Wood-based composite", "Other products", "N.D.—Not Determined"
Product category	"Structural", "Not structural", "Both", "N.D.—Not Determined"
Methods used to add value	Production process: "Efficient silvicultural treatment", "Alternative destination", "Improving decision-making in production process" "Innovative production techniques", "New product", "Innovative pretreatment", "Transformation of waste material" Valorisation of raw material: "Use of lesser-used woods", "Use of local wood", "Use of low quality wood", "Use of secondary wood materials, "Use of waste material" Product technology: "Conferring new properties", "Highlighting properties", "Improvement of the properties" Sustainability: "Cascading use", "LCA", "Recycling", "Substitution of over-exploited species", "Use of alternative adhesives", "Use of alternative varnishes", "Use of local resources" Economic aspects: "Circular bioeconomy", "Creation of short supply chains", "Global value chain", "Marketing and relational capital" Social aspects: "Collaboration and shared logic", "Direct marketing and personal contact"
Aspects of added value	"Alternative destination", "Conferring new properties", "Economic benefits", "Increased employment", "New products", "Quality/performance improvement", "Sustainability"
Outcomes of adding value	"Economic benefits", "Environmental benefits", "New potential uses", "New products", "Product quality and performance", "N.D.—Not Determined"

The last search on the databases was conducted on the 29th of December 2024 and identified 951 documents on Scopus and 1023 documents on Web of Science, yielding a total of 1974 records. Of these, 885 papers were removed because they were duplicates, 293 were excluded for not being primary research and/or open access, 27 were removed because they were not written in English, and 47 were excluded because they were published before 2014. Of the 722 remaining articles, 611 were removed after reading the titles and abstracts, as they did not meet the PICO eligibility criteria. As a result, 111 articles were selected for the qualitative analysis. The study selection process is illustrated in Figure 1.

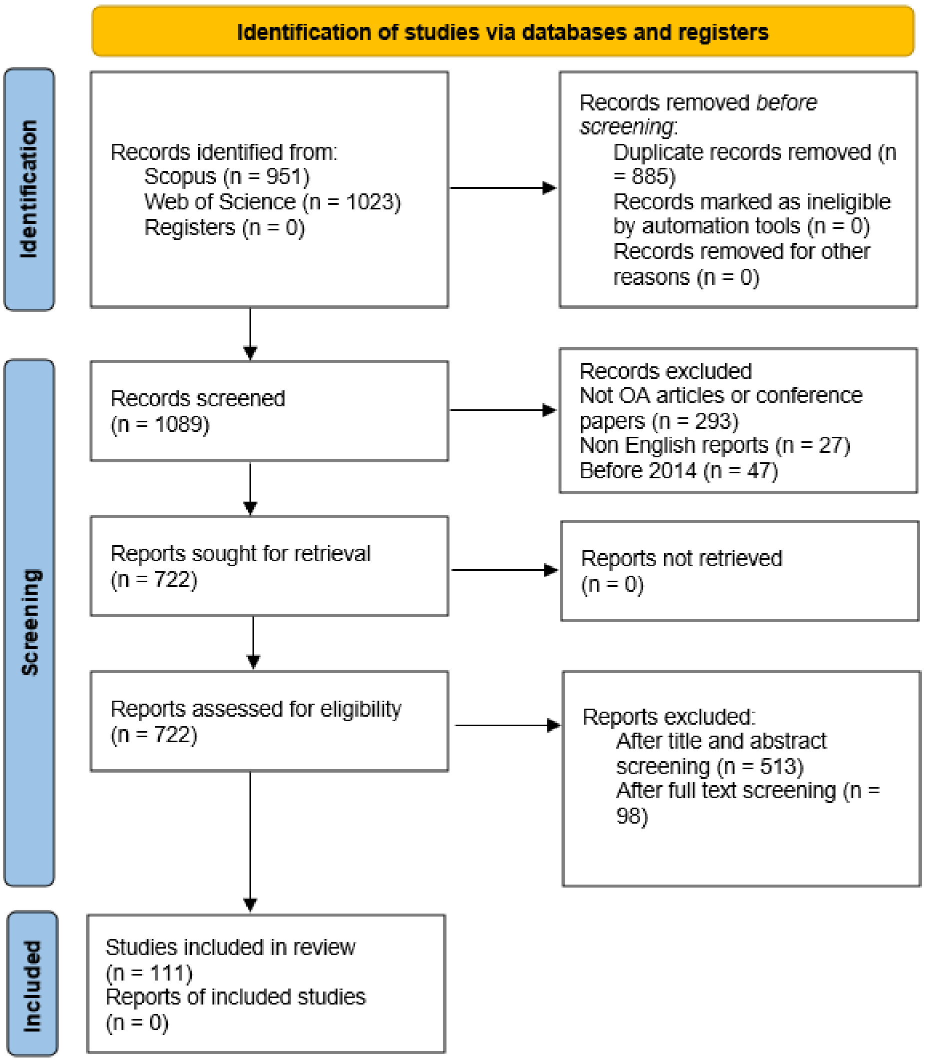

Figure 1. Flow diagram of the selection process used to identify studies for inclusion in the systematic review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (n = number of studies).

3. Results and Discussion

3.1. Descriptive Analysis of the Reviewed Studies

The annual distribution of the reviewed articles reflects the evolving research focus on added value in regard to wood-based products from 2014 to 2025 (Figure 2). In the first five years, annual publications were limited (<6%), but their number increased markedly, peaking at 17.1% between 2022 and 2024, indicating a growing interest in the field. The decline in 2025 (0.9%) is due to the ongoing nature of this year, hindering a complete assessment of the publications.

Appendix A provides a detailed overview of the selected articles, including information on document type, geographical distribution, and the journals in which the articles were published. Of the 111 records analysed, only four are proceedings papers, while the rest are peer-reviewed scientific articles. Figure 3 shows the geographical distribution of the studies, with China contributing the most publications (17.1%), followed by Brazil (12.6%), Romania (8.1%), and the United States (8.1%). A large proportion of the publications (30.6%) originates from various countries, highlighting the global interest in this topic. As illustrated in Figure 4, 25.2% of the articles were published in *Polymers* and *BioResources*, followed by *Maderas: Ciencia y Technologia* and *Forests*, which accounted for

7.5% and 5.6%, respectively. The remaining articles are spread across various journals, reflecting the diversity of the places of publication.

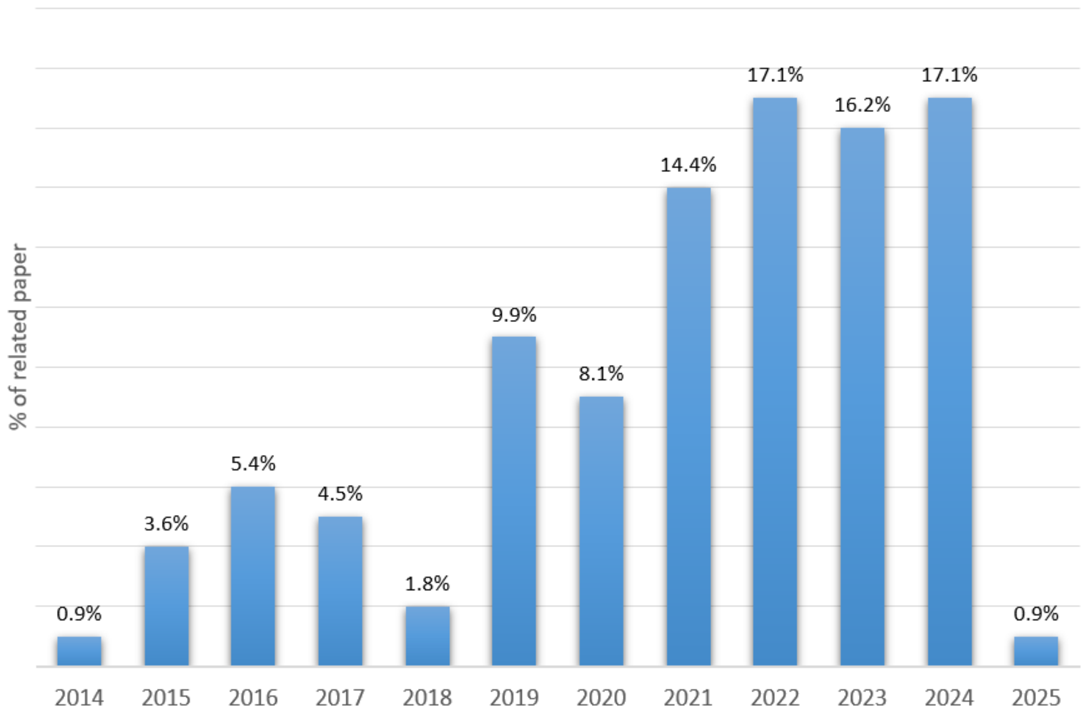

Figure 2. Chronological distribution of relevant publications included in the review.

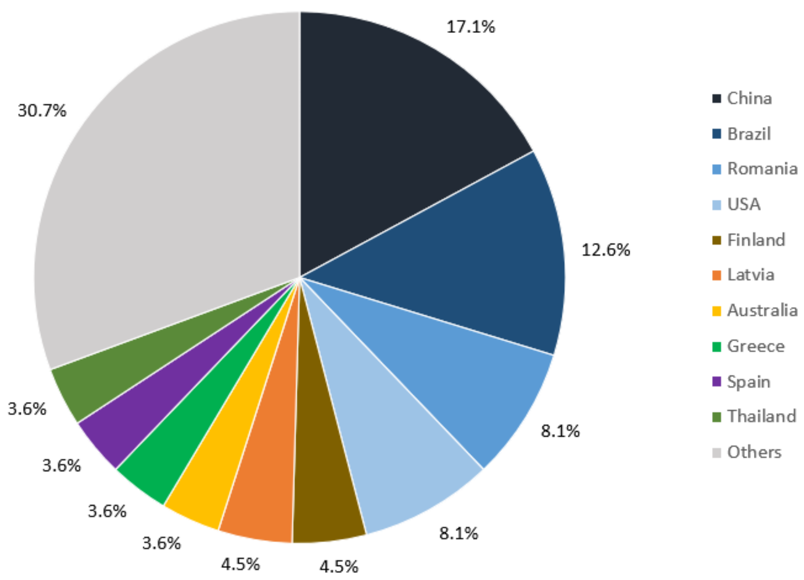

Figure 3. Top countries for research on added value for wood-based products.

3.2. "Added Value" Only as a Label or a Defined Concept

This review revealed that although the term "added value" is frequently used in the scientific literature, its definition is not elaborated upon in most studies. More than half of the reviewed papers (54.1%) lack an explicit definition, indicating that the term is often used as a label only, without further explanation. For example, the expression "value-added product" is often used simply to indicate the product itself. Cross-Laminated Timber (CLT) or veneers, for instance, are frequently labelled as higher-added-value products to distinguish them from other products such as wood pulp or biomass, without clarifying what constitutes the added value. This gap suggests a need for developing theoretical frameworks and standardised metrics to examine added value in greater depth. Such a framework could support the implementation of measures aimed at generating real impacts on wood supply chains.

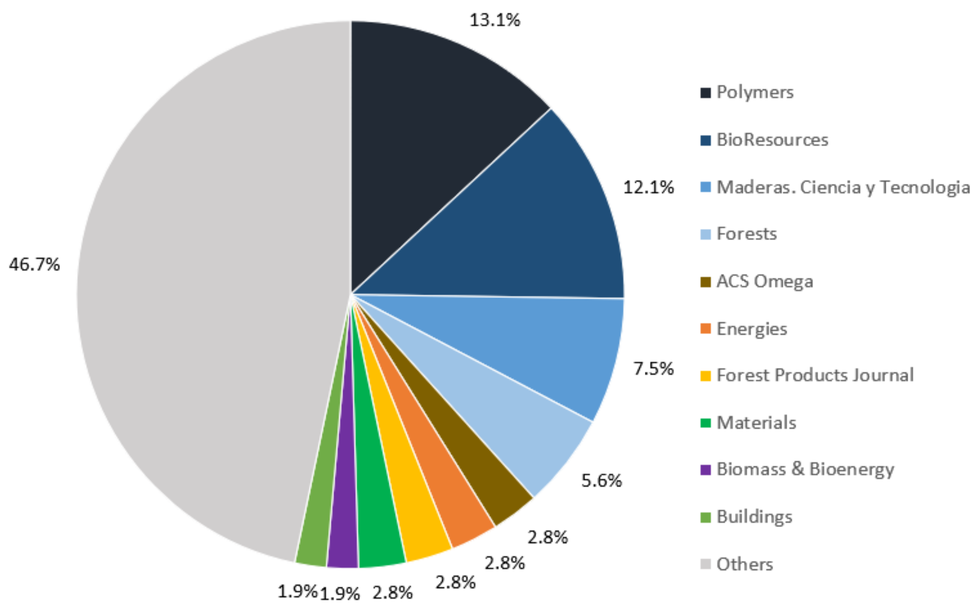

Figure 4. Top journals publishing material on added value in wood-based products.

In 22.5% of the studies, the concept can be better understood because, although not explicitly defined, its role is more relevant to the article and its meaning can be inferred from the context. However, this leaves room for misinterpretation due to the subjective interpretation of the information in the text.

In the remaining 23.4% of the reviewed studies, a specific definition of the concept is provided, which varies depending on the focus of the research. This reflects the multifaceted and complex nature of "added value", which, in the analysed articles, is mostly related to economic, environmental, and product-specific aspects. In some cases, added value is described in economic terms, such as the increase in economic value resulting from labour and capital inputs during the production process [51]. Other studies define it in terms of sustainability, e.g., finding alternatives to fossil energy to contribute to reducing greenhouse gas emissions [52]. In other cases, aesthetic characteristics—especially the colour of wood—are considered the primary added value, enhancing the product's appeal and perceived value [53].

Finally, although the search string was not strictly related to innovation, it is worth noting that the concept of "added value" is often confused with that of "innovation". However, the latter refers to the development and introduction of novelties in a process, product, or service, whether new or existing [54]. On the other hand, "added value" in the wood sector is often related to the improvement of properties or performance with the aim of creating new business opportunities. In addition, it may also include intangible aspects (see "perceived value" in Section 1.1) that are not covered by innovation.

3.3. Product Category and Methods of Adding Value

In terms of intended use, 57.5% of the articles reviewed focus on non-structural products, 16.8% focus on structural products, and 25.7% do not clearly define the end use. The last category includes articles that address the wood sector in general terms or focus on laboratory-tested solid wood specimens. This issue is linked to the frequent use of "added value" as a generic label. Addressing it also requires a detailed consideration of specific products, their potential end uses, and comparisons with benchmark products.

Regarding the specific products (Figure 5), wood-based panels are the most frequently discussed, representing the content of 25.0% of the articles reviewed, followed by wood-based composites, such as wood–plastic composites (WPCs) or lightweight wood–polyurethane (W–PU) composite foams, which account for 22.3%. A total of 13.4% of the articles do not define the product category, as they focus more broadly on the wood sector. Biomass, particularly biochar, is addressed in 13.4% of the articles, while solid wood, including laboratory-tested specimens, accounts for 8%. Structural wood-based products, namely, Cross-Laminated Timber (CLT) and Glue-Laminated Timber (GLT), represent 7.1% of the articles. The remaining categories, each accounting for less than 3% of the articles, include paper, packaging, and specific wooden objects.

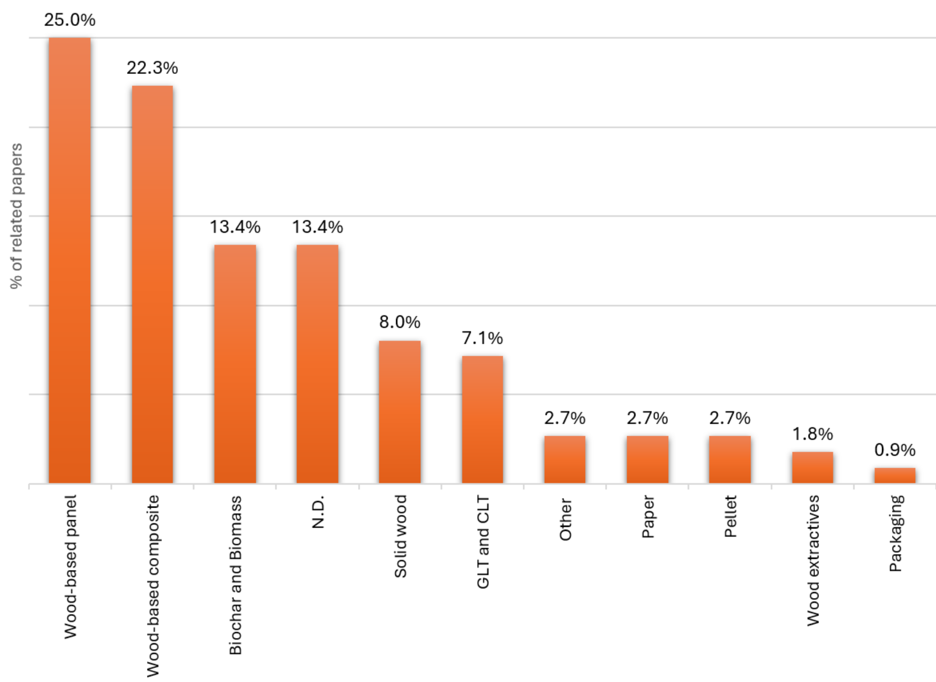

Figure 5. Types of wood products to which the concept of added value is applied in the articles analysed (percentage values refer to the related articles; N.D. = Not Determined).

The fact that the concept of added value is predominantly addressed in non-structural products may be linked to the inherent perception of structural use as a way of adding value. Also, structural products typically must comply with broader regulatory and legislative frameworks [55]. This can hinder or at least slow down innovation at the product level. On the other hand, non-structural products are often subject to lighter restrictions, providing a more flexible and dynamic space for innovation. This facilitates the development of diverse and advanced solutions to meet new market demands.

Several methods for adding value to wood-based products are considered in the reviewed studies (Figure 6). A key approach, discussed in 35.2% of the studies, focuses on the implementation of innovative production processes, including enhanced decision-making during manufacturing and pre-treatment processes. Another common method, representing 30.1% of the studies, involves the valorisation of wood as a raw material. This adds value by using lesser-known or underutilised wood species, local timber, and wood as a secondary raw material. The aim of these approaches is to enhance sustainability by reducing dependence on over-exploited resources. Sustainability is specifically addressed in 15.7% of the studies, wherein added value is related to practices like recycling and promoting the cascading use of wood. In particular, the diversification of the end uses for wood waste or byproducts represent another key aspect. Traditional methods often involve incineration for power generation. However, redirecting wood residues towards alternative ends, such as biochar or new products, can offer interesting opportunities for adding value to the product [56,57].

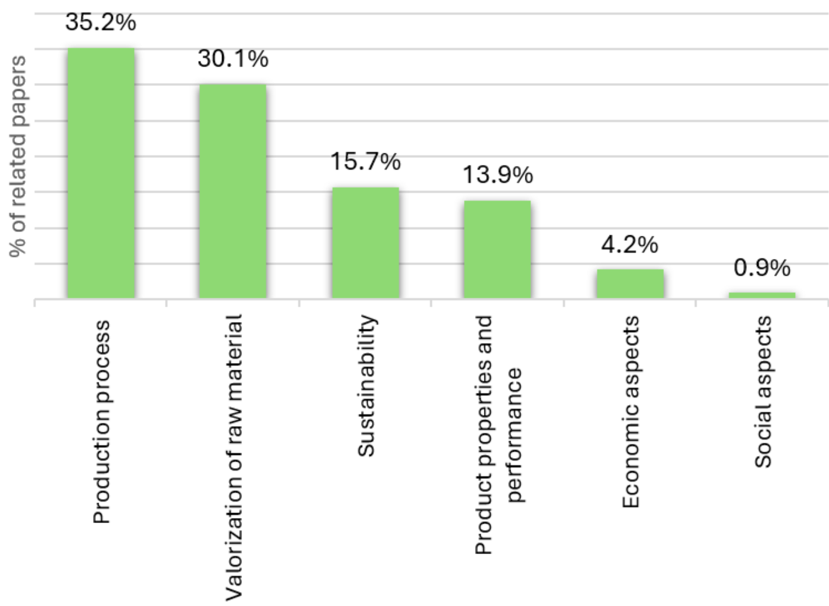

Figure 6. Methods of adding value to wood-based products considered in the reviewed articles (percentages refer to the related articles).

Product properties and performance are considered in 13.9% of the studies. Pretreatments, including chemical or thermal modification, are frequently investigated both to confer new features and improve some of the physical–mechanical characteristics of wood, particularly in terms of dimensional stability, strength, and durability. Wood modification is also proposed to facilitate the use of lower-quality or lesser-known species, thereby promoting a more efficient use of available wood resources [58,59].

Economic drivers that add value are discussed in 4.2% of the studies. These studies consider the principles of the circular economy and the enhancement of short timber supply chains along with the creation of a Global Value Chain (GVC). The economic approach typically extends beyond the individual product to encompass the entire industry, aiming to promote efficiency, enhance competitiveness, and foster business ecosystems [60].

Finally, 0.9% of the studies highlight the importance of social aspects. This is indeed a small fraction, especially when compared to the attention paid to social aspects by other scientific sectors such as agronomy [61]. Collaboration and shared decision-making among stakeholders as well as investment in human capital through training and skill development—especially in areas where manual work is crucial—are important factors in developing effective and sustainable drivers to add value and ensure there are benefits for all partners throughout a supply chain [62,63].

It is worth noting that the reviewed studies largely overlook the impact of workforce competence. This omission represents a significant gap, as human resources play a key role in enhancing added value [41]. This is particularly relevant for materials such as wood, which requires specialised expertise for optimal manufacturing and utilisation. Further research is necessary to better understand and support the role of workforce competence within wood supply chains.

Despite being distinct, the above methods of adding value are often interrelated. Innovations in one area frequently complement or enhance those in others, creating synergies across drivers. These interconnections become clearer when viewed from a broader perspective. Most studies analyse added value within isolated contexts, without considering its interconnected dimensions. A more integrated approach, as discussed in Section 1.1, is recommended to enhance the potential to create tangible added value in regard to wood in supply chains. For example, several of the added value aspects can be grouped based on environmental considerations. In this regard, innovations in manufacturing, such as the use of eco-friendly adhesives in wood-based panels, can enhance the environmental performance of products [64]. Similarly, integrating wood and plastic waste to create eco-friendly composites adds value to secondary raw materials, promotes cascading use, and contributes to resource efficiency [65,66]. Integrating such practices into sector polices is important not only for their positive environmental impacts but also the associated socio-economic benefits, such as increasing economic sustainability, creating new markets, and generating employment opportunities.

3.4. Outcomes of Adding Value

As shown in Figure 7, the reviewed studies mostly identify the benefits of adding value from an environmental perspective (41.4%). This is in line with the growing global awareness of sustainability and the need to adopt environmentally responsible practices. Indeed, as a raw material, wood holds inherent environmental value due to its renewability, high carbon storage capacity, and lower environmental impact compared to alternative materials. As discussed in Section 1.2, environmental value can be added at all stages of the life cycles of wood-based products, from responsible timber sourcing to efficient resource recovery. Extending a wood-based product's 'service life' also prolongs carbon storage, thus contributing to the mitigation of atmospheric CO_2 concentrations [67]. In addition to sustainability, these elements often provide a competitive advantage for wood products.

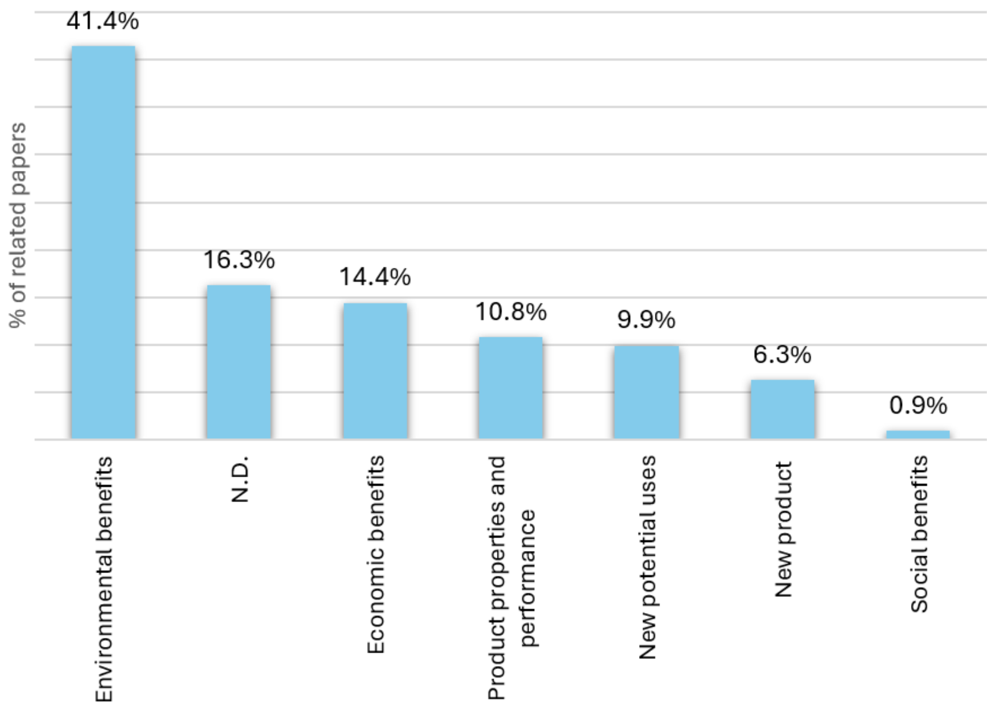

Figure 7. Outcomes of adding value identified in the reviewed articles (percentage values refer to the related articles; N.D. = Not Determined).

In 16.3% of the studies, the outcome of adding value is not explicitly defined. This is consistent with the finding discussed in Section 3.2, where "added value" is often used as a label rather than a clearly defined concept. The third most represented category is economic impact (14.4%), highlighting the role of added value in improving market competitiveness, fostering growth, and generating new business opportunities. Implementing such approaches has now become essential for effective planning and regulatory activities that guide sector policies.

Other reported outcomes include improved product properties and performance (10.8%), new potential uses (9.9%), and the development of new products (6.3%). These aspects are often discussed in relation to the importance of diversification within the wood sector. As the market for wood-based products evolves, developing novel applications and enhancing product performance become crucial for meeting emerging demands or improving specific requirements.

Finally, the relatively little emphasis on social benefits (0.9%) suggests that these are not yet considered as central outcomes in the scientific literature on added value wood-based products [68]. However, research and innovation are key components of the Industry 5.0 approach, which promotes a sustainability- and human-centric vision extending beyond mere productivity [69]. Social impacts have cross-cutting relevance throughout wood supply chains. Examples include ensuring the rights of Indigenous populations, guaranteeing adequate working conditions and wages, promoting gender equality, and supporting employment in marginal areas. Strengthening collaboration and stakeholder engagement can serve as an effective driver of job opportunities, improve corporate image, and foster local development. Drawing insights from other research fields could improve the analysis of social dimensions. A multidisciplinary approach, incorporating social science perspectives, is therefore recommended.

Finally, it is worth noting that the limited representation of economic and social aspects may partly stem from the search string used, which did not explicitly cover broader social–economic dimensions. Nonetheless, the high occurrence of environmental aspects, which were not an explicit search term, suggests that they have a stronger association with added value than economic and social factors.

4. Conclusions

Added value is relevant at all stages of the supply chains of wood-based products. This systematic literature review considered primary research articles published in English over the last ten years in order to provide a broad overview of the related drivers and assess how the scientific literature supports the implementation of added value in wood supply chains.

With regard to research questions Q1–Q4 listed in Section 1.3, this review revealed that "added value" was often not explicitly defined or only partially addressed in the reviewed studies (Q1). More than half of the reviewed studies employed the term as a general label without further clarification, while only a minority provided a specific definition. When defined, added value was most commonly associated with economic, environmental, or product-specific aspects, reflecting its multifaceted and complex nature. As for the product categories (Q2), non-structural products, especially wood-based panels, were most frequently investigated. About a quarter of the works do not define the end application of the products, which can be linked to the frequent use of "added value" as a generic label. The predominant methods for adding value (Q3) focus on production processes and the valorisation of raw materials, including innovative manufacturing techniques, the use of lesser-known wood species, and the promotion of short timber supply chains. Sustainability emerged as a key driver in numerous studies, particularly concerning recycling, cascading use, and resource efficiency. Environmental benefits were by far the most frequently discussed outcomes (Q4), highlighting the increasing emphasis on sustainability in the wood sector. Despite this, these aspects are often not directly rewarded by the market. Mechanisms, frameworks, and measures to valorise them should therefore be encouraged, for example, by strengthening their relevance in regulations or by promoting certification schemes in the marketplace.

The overview provided by this study can contribute to a deeper understanding of the main drivers related to adding value in the wood sector. This knowledge may prove useful in various contexts, including defining research priorities, improving industry competitiveness, and facilitating stakeholder engagement.

This study highlights significant gaps in the current literature concerning the concept of “added value” in regard to wood-based products. Firstly, the frequent absence of an operational definition, with the term often used merely as a label, underscores the need for theoretical frameworks and standardised metrics. Secondly, although environmental benefits are widely acknowledged, there is a notable deficit in the analysis of social im-plications. Thirdly, the role of the workforce is either neglected or only marginally considered.

Given the dynamic nature of the wood industry, further research should integrate technological innovations—such as digitisation and Industry 4.0/5.0 approaches—with agile management practices at both micro (firm level within individual companies) and macro (policy level) scales to support a sustainable and competitive transformation of this sector. Future studies should investigate in more depth how innovation in production processes and industrial strategies can create new market opportunities, enhance the perception of wood products in the value chain, and improve consumer awareness. In this way, a cross-sectoral approach, combining research, industrial policy, and marketing practices, could provide useful tools for policy makers and entrepreneurs and lead to real benefits for wood supply chains.

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Appendix A

Table A1. Articles included in the systematic review.

ID	Title	Type of Document	Country	Citation
1	Multi-Criteria Decision-Making Model for the Material Flow of Resonant Wood Production.	Scientific paper	Slovakia	[70]
2	Characterization of solid and vapor products from thermochemical conversion of municipal solid waste woody fractions.	Scientific paper	USA	[71]

Table A1. *Cont.*

ID	Title	Type of Document	Country	Citation
3	Evaluation of OSB panels using residual wood with low contents of castor oil polyurethane resin.	Scientific paper	Brazil	[72]
4	Gluing characteristics of Papua New Guinea timber species for various non-structural applications.	Scientific paper	Australia	[73]
5	Bonding performance optimization of homogeneous and hybrid hardwood CLT using the Taguchi experimental design method.	Scientific paper	USA	[74]
6	Bonding quality of two lesser-used wood species *Brachystegia spiciformis* and *Julbernardia globiflora* from Mozambique.	Scientific paper	Brazil	[75]
7	Physicochemical characterization and thermal behavior of different wood species from the Amazon Biome.	Scientific paper	Brazil	[76]
8	Integrating offline object tracking, signal processing, and artificial intelligence to classify relevant events in sawmilling operations.	Scientific paper	Romania	[77]
9	Massaranduba sawdust: A potential source of charcoal and activated carbon.	Scientific paper	Brazil	[78]
10	Influence of coupling agent in compatibility of post-consumer HDPE in thermoplastic composites reinforced with eucalyptus fiber	Scientific paper	Brazil	[65]
11	Rendering wood veneers flexible and electrically conductive through delignification and electroless Ni plating.	Scientific paper	China	[79]
12	Visual detection application of lightweight convolution and deep residual networks in wood production.	Scientific paper	China	[80]
13	Study on the dyeing and fastness properties of ash veneer with acid dyes.	Scientific paper	South Korea	[81]
14	Some properties of wood plastic composites made from rubberwood, recycled plastic and silica.	Scientific paper	Thailand	[82]
15	assessment of the conversion of biomass and industrial waste products to activated carbon.	Scientific paper	USA	[83]
16	Anatomical characterization of black wattle wood for the pulp and paper production.	Scientific paper	Brazil	[84]
17	Acoustic and strength characterization of particleboard and micronized rubber powder composites.	Scientific paper	USA	[85]
18	Fabrication of PVA–Silica sol wood composites via delignification and freezing pretreatment.	Scientific paper	China	[86]
19	The influence of fly ash on the mechanical properties of water immersed all waste composites.	Scientific paper	Romania	[87]
20	Decision-making model for the specification of wood as an input for the production of wooden musical instruments.	Scientific paper	Slovakia	[88]
21	Analysis of wood products from an added value perspective: The Uruguayan forestry case.	Scientific paper	Uruguay	[51]
22	Some properties of linoleum and wood laminated flooring panels with magnesium substrate.	Scientific paper	Turkey	[89]
23	Strong and durable wood designed by cell wall bulking combined with cell lumen filling.	Scientific paper	China	[90]

Table A1. *Cont.*

ID	Title	Type of Document	Country	Citation
24	Influence of age and trunk positions on physicomechanical properties of *Anthocleista grandiflora* Gilg wood.	Scientific paper	Ghana	[91]
25	Heat treatment of Tunisian soft wood species: Effect on the durability, chemical modifications and mechanical properties.	Scientific paper	Tunisia	[92]
26	Financial analysis of innovative wood products and carbon finance to support forest restoration in California.	Scientific paper	USA	[93]
27	Particleboards produced with different proportions of *Hevea brasiliensis*: Residual wood valorization in higher value added products.	Scientific paper	Brazil	[94]
28	Are relational capital and marketing important? The case of the wood sector of Galicia (Spain) and Portugal.	Scientific paper	Spain	[95]
29	Cross-laminated timber rocking walls with slip-friction connections.	Scientific paper	USA	[96]
30	Physical and mechanical properties of eco-friendly composites made from wood dust and recycled polystyrene.	Scientific paper	Greece	[97]
31	Can structural timber foster short procurement chains within Mediterranean forests? A research case in Sardinia.	Scientific paper	Italy	[98]
32	A study on properties of charcoal producing from alien tree species: *Cinnamomum burmannii*.	Scientific paper	Taiwan	[99]
33	Acrylic resin filling cell lumen enabled laminated poplar veneer lumber as structural building material.	Scientific paper	China	[100]
34	Board assignment heuristics for nail laminated out-of-grade timber.	Scientific paper	Australia	[101]
35	Structural properties of commercial australian plantation hardwood CLT.	Scientific paper	Australia	[102]
36	Characterization of the wood properties of *Cedrelinga cateniformis* as substitute for timbers used for window manufacturing and outdoor applications.	Scientific paper	Germany	[103]
37	Effect of microwave pretreatment on permeability and drying properties of wood.	Scientific paper	China	[104]
38	Ex-ante eco-efficiency assessment of dendromass production: conception and experiences of an innovation project.	Scientific paper	Austria	[105]
39	Effects of heat treatment on the color change and dimensional stability of *Gmelina arborea* and *Melia azedarach* woods.	Proceedings paper	Indonesia	[106]
40	Color change and consumer preferences towards color of heat-treated Korean white pine and royal paulownia woods.	Scientific paper	South Korea	[107]
41	Probing the effects of density on combustion performance of cement-bonded particleboard produced from wood processing residues.	Scientific paper	China	[108]
42	A new type of engineered wood product: Cross-laminated-thick veneers.	Scientific paper	China	[109]
43	Reducing waste to improve product quality in the wooden pallet production process by using lean six sigma approach in PT.	Proceedings paper	Indonesia	[110]

Table A1. *Cont.*

ID	Title	Type of Document	Country	Citation
44	MOE distribution in visually graded *Ponderosa Pine* lumber harvested from restoration programs in Southern Oregon and Northern California.	Scientific paper	USA	[111]
45	Productivity and costs of forest cutting in a pine stand under two thinning methods.	Scientific paper	Brazil	[112]
46	The status, trend, and global position of China's forestry industry: an anatomy based on the global value chain paradigm.	Scientific paper	China	[113]
47	Structural application of lightweight panels made of waste cardboard and beech veneer.	Scientific paper	Bulgaria	[114]
48	Changes of meranti, padauk, and merbau wood lignin during the ThermoWood Process.	Scientific paper	Slovakia	[115]
49	Preparation of water-based alkyl ketene dimer (AKD) nanoparticles and their use in superhydrophobic treatments of value-added teakwood products.	Scientific paper	Thailand	[116]
50	Some exploitation properties of wood plastic composites (WPC), based on high density polyethylene and timber industry waste.	Scientific paper	Latvia	[117]
51	Can small and medium-sized companies increase the value added from wood-based side streams?.	Scientific paper	Finland	[118]
52	Liquefaction behaviour of twelve tropical hardwood species in phenol.	Scientific paper	India	[119]
53	Value added and employment effects in Finland when wood fibre is substituted for plastic in food packaging-A case study.	Scientific paper	Finland	[120]
54	Strategic pathways for a bioeconomy with high value-added products: Lessons learnt from the Latvian forest sector.	Scientific paper	Latvia	[121]
55	Impact of thermal treatment on the properties of assacú (*Hura crepitans* L.) and murici (*Byrsonima crispa* A.Juss.) Amazon woods.	Scientific paper	Brazil	[59]
56	Properties and cost of natural rubber latex foam using biomass ash filler from agarwood pellets.	Scientific paper	Thailand	[122]
57	Effects of ultrasound pretreatment on microstructure and drying characteristics of *Eucalyptus urophylla* × *E. grandis*.	Scientific paper	China	[123]
58	Preparation and physicochemical properties of biochar from the pyrolysis of pruning waste of typical fruit tee in North China.	Scientific paper	China	[124]
59	Grading of recovered Norway spruce (*Picea abies*) timber for structural purposes.	Scientific paper	Spain	[125]
60	Sustainability impact assessment of forest bioenergy value chains in Quebec (Canada)-A ToSIA approach.	Scientific paper	Canada	[126]
61	Bending behaviour of cross-laminated timber stressed-skin panels manufactured with mountain pine (*Pinus uncinata* Ramond ex DC.).	Scientific paper	Spain	[127]
62	Increasing the calorific properties of sawdust waste from pellets by torrefaction.	Scientific paper	Romania	[128]
63	Effects and modeling of sawdust torrefaction for beech pellets.	Scientific paper	Romania	[129]

Table A1. *Cont.*

ID	Title	Type of Document	Country	Citation
64	Effect of incorporation of lignin as bio-polyol on the performance of rigid lightweight wood–polyurethane composite foams.	Scientific paper	China	[130]
65	Turning trash to treasure: the influence of carbon waste source on the photothermal behaviour of plasmonic titanium carbide interfaces.	Scientific paper	Canada	[131]
66	Physico-mechanical properties of the wood of freijo, *Cordia goeldiana* (Boraginacea), produced in a multi-stratified agroforestry system in the southwestern Amazon.	Scientific paper	Brazil	[132]
67	Janka hardness evaluation of plantation-grown *Eucalyptus nitens* for engineered flooring applications.	Scientific paper	Australia	[133]
68	Evaluation of pressing time in the production of edge glued panel with adhesive polyurethane derived from castor oil.	Scientific paper	Brazil	[64]
69	Sustainable thermal insulation biocomposites from rice husk, wheat husk, wood fibers and textile waste fibers: elaboration and performances evaluation.	Scientific paper	France	[134]
70	Properties of 3D-printed wood sawdust-reinforced PLA composites.	Scientific paper	Turkey	[135]
71	Using deciduous branch wood and conifer spindle wood to manufacture panels with transverse structure.	Scientific paper	Romania	[136]
72	Ecofriendly panels for building with eucalyptus sawdust and vegetal polyurethane resin: a mechanical evaluation.	Scientific paper	Brazil	[137]
73	*Eucalyptus*-based Glued Laminated Timber: evaluation and prediction of its properties by non-destructive techniques.	Scientific paper	Brazil	[138]
74	Characterisation of *Rhizophora* particleboard using bio-oil-based phenol formaldehyde (PF) resin.	Scientific paper	Malaysia	[56]
75	Impact of torrefaction process temperature on the energy content and chemical composition of stool tree (*Alstonia congenisis* Engl) woody biomass.	Scientific paper	Nigeria	[139]
76	Wood waste valorization: ethanol based organosolv as a promising recycling process.	Scientific paper	Italy	[57]
77	Strategy for the analysis of lignocellulosic biomass to select a viable transformation route in the Colombian context.	Scientific paper	Colombia	[140]
78	Characterization of birch wood residue after 2-furaldehyde obtaining, for further integration in biorefinery processing.	Scientific paper	Latvia	[141]
79	Residual birch wood lignocellulose after 2-furaldehyde production as a potential feedstock for obtaining fiber.	Scientific paper	Latvia	[142]
80	Quantitative analysis of feedstock structural properties can help to produce willow biochar with homogenous pore system.	Scientific paper	Finland	[143]
81	Success factors of wood veneer as an overlay material for panel-based furniture manufacturing in Malaysia.	Scientific paper	Malaysia	[144]
82	Valorization of hazardous organic solid wastes towards fuels and chemicals via fast (catalytic) pyrolysis.	Scientific paper	Greece	[145]
83	Valorization of heat-treated wood after service life through a cascading process for the production of lignocellulosic derivatives.	Scientific paper	Spain	[146]

Table A1. *Cont.*

ID	Title	Type of Document	Country	Citation
84	Feasibility of bonding high-moisture-content wood using *Nothofagus* chilean species.	Scientific paper	Chile	[147]
85	Effect of heat treatment on colour changes of black alder and beech veneers.	Scientific paper	Romania	[148]
86	Glossiness evaluation of coated wood surfaces as function of varnish type and exposure to different conditions.	Scientific paper	Romania	[149]
87	Some coating properties of black alder wood as a function of varnish type and application method.	Scientific paper	Romania	[150]
88	Oak biomass in the form of wood, bark, brushwood, leaves and acorns in the production process of multifunctional biochar.	Scientific paper	Poland	[151]
89	Perceptions of producers of small wooden objects in Brazil's central-west region about highlighted attributes of nine species from the Caatinga biome.	Scientific paper	Brazil	[53]
90	Characterization of pellets produced from extracted sawdust: effect of cooling conditions and binder addition on composition, mechanical and thermochemical properties.	Scientific paper	Finland	[152]
91	Mechanical property of 9 years old thinning of teak plantation in Thailand.	Proceedings paper	Greece	[153]
92	Novel biodegradable poly (lactic acid)/wood leachate composites: investigation of antibacterial, mechanical, morphological, and thermal properties.	Scientific paper	Iran	[154]
93	Effect of furfurylation on hierarchical porous structure of poplar wood.	Scientific paper	China	[155]
94	Evaluation of dimensional stability, surface roughness, colour, flexural properties and decay resistance of thermically modified *Acacia auriculiformis*.	Scientific paper	India	[156]
95	Structure-property relationships of hydrothermally treated western hemlock.	Scientific paper	USA	[58]
96	Developing and evaluating composites based on plantation eucalyptus rotary-cut veneer and high-density polyethylene film as novel building materials.	Scientific paper	China	[157]
97	Wood fibres as additives in mortars: A sustainable reinforcement.	Proceedings paper	Greece	[158]
98	Validation of sustainability benchmarking tool in the context of value-added wood products manufacturing activities.	Scientific paper	USA	[159]
99	The re-/up-cycling of wood waste in wood-polymer composites (WPCs) for common applications.	Scientific paper	Romania	[160]
100	Hygromorphic response dynamics of 3D-printed wood-PLA composite bilayer actuators.	Scientific paper	Slovenia	[66]
101	Collaboration and shared logic for creating value-added in three Finnish wooden multi-storey building projects.	Scientific paper	Finland	[161]
102	Supply network configuration archetypes for the circular exploitation of solid waste.	Scientific paper	Greece	[162]
103	Evaluation of some physico-mechanical properties and formaldehyde emission of ecological chipboards produced from annual residue plant stems.	Scientific paper	Turkey	[163]

Table A1. *Cont.*

ID	Title	Type of Document	Country	Citation
104	Wood waste turned into value added products: Thermal plasticization by benzylation process.	Scientific paper	Turkey	[164]
105	Effect of hot-pressing temperature on the properties of eco-friendly fiberboard panels bonded with hydrolysis lignin and phenol–formaldehyde resin.	Scientific paper	Bulgaria	[165]
106	Characteristics of the waste wood biomass and its effect on the properties of wood sanding dust/recycled PP composite.	Scientific paper	Latvia	[166]
107	Regenerated waste tire powders as fillers for wood fiber composites.	Scientific paper	China	[167]
108	Construction of nanofibrillar networked wood aerogels derived from typical softwood and hardwood: a comparative study on the in situ formation mechanism of nanofibrillar networks.	Scientific paper	China	[168]
109	The characteristics of moisture and shrinkage of *Eucalyptus urophylla* × *E. grandis* wood during conventional drying.	Scientific paper	China	[169]
110	High-strength, thermally stable, and processable wood fiber/polyamide composites for engineering structural components.	Scientific paper	China	[170]
111	Technical and benefit evaluation of fruit-wood waste gasification heating coproduction of an activated carbon system.	Scientific paper	China	[52]

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